Water Quality Improvement Plan
for the
Statewide Beach Bacteria

Total Maximum Daily Loads for:
Pathogen Indicators (*E. coli*)

Prepared by:
Jason Palmer, Andrew Frana,
and James A. Hallmark, P.E.

Iowa Department of Natural Resources
Watershed Improvement Section
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Units of measure:

ac	acre	M	meter
cfs	cubic feet per second	mg	milligram
cfu	colony-forming unit	Mg	megagram (= 1 mt)
cm	centimeter	mi	mile
cms	cubic meters per second	mL	milliliter
d	day	mo	month
g	gram	mt	metric ton (= 1 Mg)
ha	hectare	orgs	E. *coli* organisms
hm	hectometer	ppm	parts per million
hr	hour	ppb	parts per billion
in	inch	s	second
kg	kilogram	t	ton (English)
km	kilometer	yd	yard
L	liter	yr	year
lb	pound		

Other abbreviations:

AFO	animal feeding operation
BMP	best management practice
Chl-a	chlorophyll a
E. coli	Escherichia coli
GM	geometric mean (pertains to WQS for E. coli, = 126 orgs/ 100 mL)
LDC	load duration curve
N	nitrogen
ortho-P	ortho-phosphate
P	phosphorus
SSM	single-sample max (pertains to WQS for E. coli, = 235 orgs/ 100 mL)
TN	total nitrogen
TP	total phosphorus
WQS	water quality standard

General Report Summary

What is the purpose of this report?

This Water Quality Improvement Plan (WQIP) serves multiple purposes. First, it is a resource for increased understanding of watershed and water quality conditions in lake systems throughout the state. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) for impaired waterbodies. Third, it provides a foundation for watershed and water quality improvement efforts. Finally, it may be useful for obtaining financial assistance to implement projects to remove the included water bodies from the federal 303(d) list of impaired waters.

What's wrong with recreational swimming zones in lakes?

As of the 2016 impaired waters list there are 34 lakes in the State of Iowa that are not supporting the primary contact recreation (Class A1) use due to high levels of fecal indicator bacteria (FIB) called Escherichia coli (*E. coli*). Primary contact recreation includes activities that involve direct contact with the water such as swimming and wading. High *E. coli* levels in a waterbody can indicate the likelihood of the presence of potentially harmful bacteria and viruses (also called pathogens). Humans can become ill if they come into contact with and / or ingest water that contains pathogens; however, it is important to note that not all forms of *E. coli* (the fecal indicator bacteria) are pathogens.

What is causing the problem?

E. coli and harmful pathogens found in a lake or stream can originate from point or nonpoint sources of pollution, or a combination of both. Point sources of pollution are easily identified sources that enter a stream or lake at a distinct location, such as a wastewater treatment plant discharge. Nonpoint sources of pollution are discharged in a more indirect and diffuse manner, and are often more difficult to locate and quantify. Nonpoint source pollution is usually carried with rainfall or snowmelt over the land surface and into a nearby lake or stream.

From the data presented in this WQIP it can be seen that 1) there is a disconnect between the open lake environment and *E. coli* contamination in the swimming zone, which is driven by conditions in the foreshore beach environment and not from the lake watershed and 2) the main source of *E. coli* in these cases is the geese and other shore birds that populate the beaches during the recreational season.

What can be done to improve recreational swimming zones in lakes?

To improve the water quality in the recreational swimming zones so that primary contact and children's recreation are fully supported, the amount of bacteria entering the near shore beach volume (NSBV) of the lake must be reduced. Accomplishing this will require management practices to reduce the goose and other shore bird population on the beaches or ways to remove the fecal matter from the beach areas.

Because the source of the impairment comes from the beach environment this WQIP will focus on the management of the beach watershed area.

Who is responsible for cleaner recreational swimming zones?

Responsibility to improve water quality within the swimming zone will fall mostly upon the agency that manages the beach and swimming zones. This is due to the fact that the population of geese and other shore birds must be managed, which is a difficult task for individual citizens to do. People who recreate in the area also have a responsibility to manage pets while they are in the beach watershed area.

Does a TMDL guarantee water quality improvement?
The Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this WQIP. The TMDL itself is only a document, and without implementation, will not improve water quality. Therefore, a basic implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

What are the primary challenges for water quality implementation?
The primary challenges faced in these cases is limiting the goose and other shore bird populations on the beaches or removing the fecal matter before it transfers into the water. This will require implementation of multiple practices and possibly changing practices from year to year.

Future Submittals
As previously stated, there are 34 lakes in the State of Iowa listed on the 2016 impaired waters list that are not supporting the primary contact recreation. The initial submittal of this WQIP will include 3 lakes; Hickory Grove, Clear Lake (McIntosh Woods State Park and Clear Lake State Park), and Nine Eagles. Subsequent lakes will be submitted as addendums to this WQIP.

Figure 1 shows the location of the impaired lakes and identifies those lakes that TMDLs have been submitted. Table 1 lists the lakes, indicates the date the TMDL was submitted, the associated chapter of the lake TMDL, HUC-8 location, county location, and other general information related to the lake.

As additional beach bacteria TMDLs are prepared and submitted Figure 1 and Table 1 will be amended to reflect the new submittals.

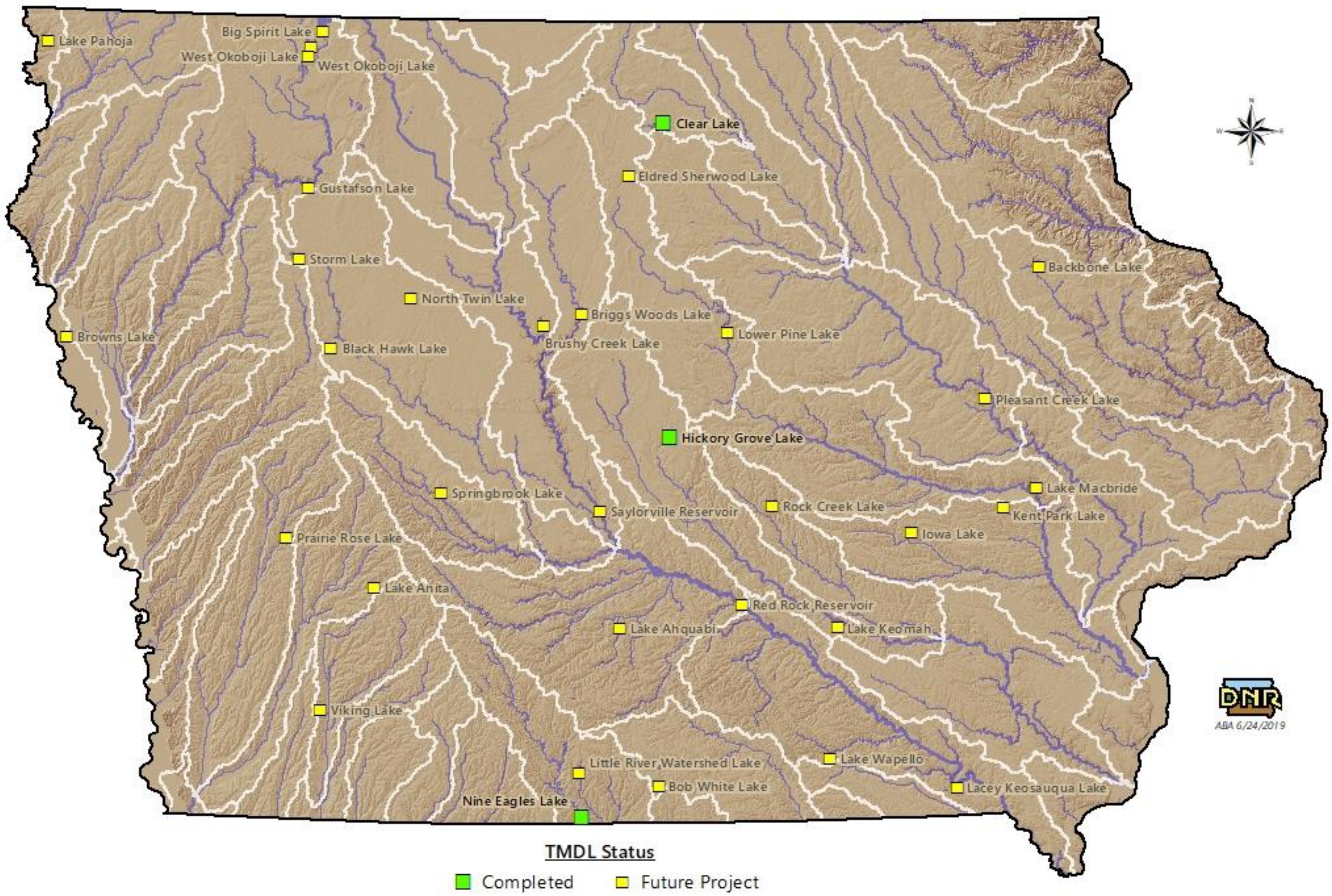


Figure 1. Location Map of Lakes Impaired for *E. coli*.

Table 1. Impaired Lakes for *E. coli*.

Lake Name	Chapter	TMDL Year Submitted	ADB Code	HUC-8 Subbasin	County	Cycle Listed
Backbone Lake	---	---	01-MAQ-20	Maquoketa	Delaware	2004
Big Spirit Lake	---	---	06-LSR-1655	Little Sioux	Dickinson	2008
Black Hawk Lake	---	---	04-RAC-1134	North Raccoon	Sac	2016
Bob White Lake	---	---	05-CHA-1338	Upper Chariton	Wayne	2004
Briggs Woods Lake	---	---	04-UDM-1255	Boone	Hamilton	2016
Browns Lake	---	---	06-WEM-1735	Blackbird-Soldier	Woodbury	2008
Brushy Creek Lake	---	---	04-UDM-1276	Middle Des Moines	Webster	2012
Clear Lake[(1)] Clear Lake St Park McIntosh Woods	5	2020	02-WIN-841	Winnebago	Cerro Gordo	 2004 2010
Eldred Sherwood Lake	---	---	02-IOW-773	Upper Iowa	Hancock	2008
Gustafson Lake	---	---	06-LSR-1625	Little Sioux	Buena Vista	2014
Hickory Grove Lake	4	2020	03-SSK-950	South Skunk	Story	2008
Iowa Lake	---	---	02-IOW-677	Lower Iowa	Iowa	2012
Kent Park Lake	---	---	02-IOW-694	Lower Iowa	Johnson	2014
Lacey Keosauqua Lake	---	---	04-LDM-1008	Lower Des Moines	Van Buren	2012
Lake Ahquabi	---	---	04-LDM-1080	Lake Red Rock	Warren	2012
Lake Anita	---	---	05-NSH-1435	East Nishnabotna	Cass	2010
Lake Keomah	---	---	03-SSK-930	South Skunk	Mahaska	2008
Lake Macbride	---	---	02-IOW-629	Middle Iowa	Johnson	2006
Lake Pahoja	---	---	06-BSR-1532	Lower Big Sioux	Lyon	2016
Lake Wapello	---	---	04-LDM-1035	Lower Des Moines	Davis	2012
Little River Lake	---	---	05-GRA-1358	Thompson	Decatur	2014
Lower Pine Lake	---	---	02-IOW-758	Upper Iowa	Hardin	2006
Nine Eagles Lake	6	2020	05-GRA-1361	Thompson	Decatur	2006
North Twin Lake	---	---	04-RAC-1167	North Raccoon	Calhoun	2012
Pleasant Creek Lake	---	---	02-CED-459	Middle Cedar	Linn	2012
Prairie Rose Lake	---	---	05-NSH-1462	West Nishnabotna	Shelby	2012
Red Rock Reservoir	---	---	04-LDM-1017	Lake Red Rock	Marion	2014
Rock Creek Lake	---	---	03-NSK-865	North Skunk	Jasper	2006
Saylorville Reservoir	---	---	04-UDM-1213	Middle Des Moines	Polk	2006
Springbrook Lake	---	---	04-RAC-1196	South Raccoon	Guthrie	2012
Storm Lake	---	---	04-RAC-1143	North Raccoon	Buena Vista	2010
Viking Lake	---	---	05-NOD-1407	West Nowaway	Montgomery	2006
West Okoboji Lake	---	---	06-LSR-1653	Little Sioux	Dickinson	2014
West Okoboji Lake	---	---	06-LSR-2066	Little Sioux	Dickinson	2006

(1) Clear Lake is impaired due to water quality at two beaches Clear Lake State Park and McIntosh Woods State Park. Clear Lake was initially impaired for bacteria during the 2004 cycle due to water samples from Clear Lake State Park. Water quality samples from McIntosh Woods State Park showed an impairment for bacteria in the 2010 cycle.

Required Elements of the TMDL

This Water Quality Improvement Plan has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7 in compliance with the Clean Water Act. These regulations and consequent TMDL development are summarized below in Table 2.

Table 2. Technical Elements of the TMDL.

Name and geographic location of the impaired or threatened waterbodies for which the TMDL is being established:	As of the 2016 impaired waters list (303(d)) there are 34 lakes in the state that are not supporting the primary contact recreation (Class A1) use due to high levels of fecal indicator bacteria (FIB) called Escherichia coli (*E. coli*). Figure 1 is a map showing the location of the lakes. Table 1 is a listing of the lakes.
Surface water classification and designated uses:	A1 – Primary Contact B(LW) – Aquatic life HH – Human health (fish consumption)
Impaired beneficial uses:	A1 – Primary Contact (March 15 to November 15)
TMDL priority level:	Priority Tier II
Identification of the pollutants and applicable water quality standards (WQS):	Pathogen Indicator, *E. coli*. Primary contact recreational (Class A1) use is not supported due to violation of the *E. coli* Water Quality Standard criteria of 126 organisms/ 100 mL for the geometric mean and 235 organisms/ 100 mL for the single sample maximum (SSM). These standards only apply during the recreational season of March 15 – November 15.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	The target is a geometric mean of 126 *E. coli* organisms/ 100 mL and a SSM of 235 *E. coli* organism/ 100 mL
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	The *E. coli* load departure from capacity has been calculated for each lake included within this WQIP.
Identification of pollution source categories:	There are no regulated point source discharges of *E. coli* in the watershed. Nonpoint sources of *E. coli* include fecal matter from water fowl, mainly geese that maintain a presence on and near the beach areas.
Wasteload allocations (WLAs) for pollutants from point sources:	There are a limited number of point source discharges in the lakes watershed area. However, it is demonstrated in this WQIP that theses point sources do not contribute to the impairment.
Load allocations (LAs) for pollutants from nonpoint sources:	Load allocations are listed for each lake in their respective chapters.
A margin of safety (MOS):	An explicit 10 percent MOS is incorporated into this TMDL.

Consideration of seasonal variation:	These TMDL’s were developed based on the Iowa WQS primary contact recreation season that runs from March 15 to November 15. Since there are no point sources and the assumption is that the swimming zone volume is constant, the LA will be the same for any given period of time.
Reasonable assurance that load and wasteload allocations will be met:	Since there are no point sources in the beach watershed areas the only concern would be for nonpoint sources. For reasonable assurances nonpoint sources must satisfy the following: • They must apply to the pollutant of concern. • They will be implemented expeditiously. • They will be accomplished through effective programs. • They will be supported by adequate water quality funding.
Allowance for reasonably foreseeable increases in pollutant loads:	The TMDL’s focus on the beach shed areas. These areas are small and it is not anticipated that there will be any increases in pollutant loads to this area.
Implementation plan:	A general implementation plan is outlined in Chapter 3 as a guide for possible solutions to reduce *E. coli* in the recreational areas. If needed, specific plans may be provided in individual chapters covered specific water bodies.

1. Introduction

The Federal Clean Water Act requires states to assess their waterbodies every even numbered year and incorporate these assessments into the 305(b) Water Quality Assessment Report. Assessed lakes and streams that do not meet the Iowa Water Quality Standards (WQS) criteria are placed on the 303(d) Impaired Waters List. Subsequently, a Total Maximum Daily Load (TMDL) for each pollutant must be calculated and a WQIP written for each impaired water body.

A TMDL is a calculation of the maximum amount of pollution that a waterbody can tolerate without exceeding WQS and impairing the waterbody's designated uses. The TMDL calculation is represented by the following general equation:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

Where: TMDL = total maximum daily load
LC = loading capacity
ΣWLA = sum of wasteload allocations (point sources)
ΣLA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

One purpose of this Water Quality Improvement Plan (WQIP) is to provide the TMDL for *E. coli* and satisfy the requirements of the Clean Water Act. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, assist the development of funding applications and a comprehensive watershed management plan, and guide water quality improvement efforts.

This WQIP includes an assessment of the existing *E. coli* loads to each of the impaired segments in the basin and a determination of how much *E. coli* each beach can tolerate and still provide for primary contact recreational use. The WQIP also includes descriptions of potential solutions to the impairments. This group of solutions is presented as a toolbox of best management practices (BMPs) for reducing *E. coli* concentrations, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the general implementation plan in Chapter 3. If specific practices are required at local beaches those practices will be addressed in their respective TMDL chapters.

The WQIP will be of little value to real water quality improvement unless watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies.

Implementation of BMPs should be integrated with collection of water quality data as part of the ongoing monitoring plan, evaluation of collected data, and modification of the implementation plan (if necessary). Monitoring is a crucial element to assess the attainment of WQS and designated uses, to determine if water quality is improving, degrading, or unchanged, and to assess the effectiveness of implementation activities and the possible need for additional BMPs. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Chapter 3.

2. Sampling and Data Collection

2.1. Spatial and temporal trends of E. coli concentrations on three lakes with impaired recreational beaches

Swimming advisories are commonly posted at public beaches across Iowa every season. Weekly monitoring of public swimming zones at state and county beaches have resulted in the impairment of numerous lakes for Fecal Indicator Bacteria (FIB) contamination, a violation of the State of Iowa's water quality standards. These swimming beach based impairments result in whole lake waterbodies being listed as impaired on the states 305(b) assessment each year. These impairment listings do not accurately reflect the condition(s) of the larger lake environment outside the swimming zone and fail to account for beach proximate conditions in the assessment process.

The Iowa Department of Natural Resources (Iowa DNR) maintains an ambient beach bacteria monitoring network at roughly 34 lakes and periodically accepts samples from numerous county managed systems. Data from these sampling points are used to assess the safety of the swimming environment and provide a status of the attainment of recreational uses of the lake system. All but three of the 34 FIB impaired lake systems in Iowa were identified as a result of this monitoring network.

Traditionally, management of these systems has assumed that the larger watershed serves as the primary source of FIB to the recreational areas. However, the trends of FIB contamination in small inland lake swimming zones appear to follow those similar trends along coastlines and larger lake shores across North America. Sampling shows a disconnect between the open lake environment and FIB contamination in the swimming zone, which will be driven by conditions in the foreshore sand environment. An extensive study was established to assess the relationships between the nearshore beach environment, open lake conditions and watershed delivery of FIB (*E. coli*) in three representative beach / lake systems currently impaired for FIB contamination across Iowa. Following are the results of this study.

2.2. Study Sites

Three lake systems with established beach *E. coli* bacteria impairments, Nine Eagles Lake (IA 05-GRA-1361), Hickory Grove Lake (IA 03-SSK-950), and McIntosh Woods Beach on Clear Lake (IA 02-WIN-841), were sampled across two seasons as part of this study (Figure 2-1). The Class A1 uses (primary contact recreation) of these three lakes are currently designated as impaired due to violations of *E. coli* water quality standards and are on the state's 2016 303(d) impaired water bodies list. Each of these three beaches is monitored weekly by the Iowa Department of Natural Resources (DNR) Ambient Water Quality Monitoring and Assessment Program from mid-May until Labor Day each season. Data from this sampling network is used to provide the public with information regarding conditions in the swimming zone and to assess the primary contact recreational uses (A1) of the lake for the state's 303(d) impaired waterbodies list.

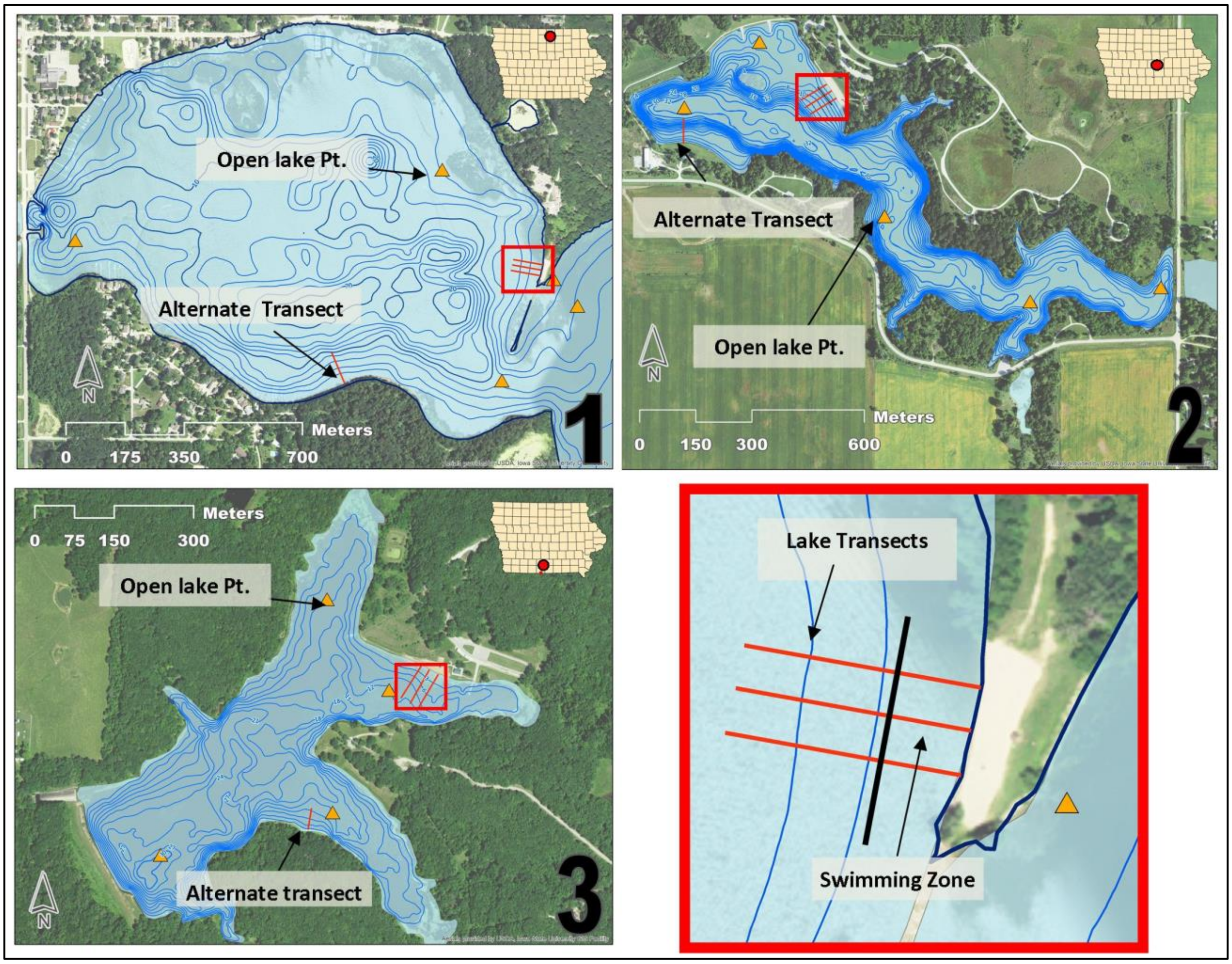


Figure 2-1. Lake Locations and Sampling Layout for all Three Systems: (1) McIntosh Woods Beach, (2) Hickory Grove Lake, and (3) Nine eagles Lake. The insert shows the transect locations where water and sand sediments were collected (red outline on each lake).

Hickory Grove and Nine Eagles lakes are man-made impoundments while the third system, Clear Lake, is a natural glacial lake located in Northern Iowa. Two of the three systems (Clear Lake and Hickory Grove Lake) are located on the Des Moines Lobe landform region, Iowa's youngest landscape, created between 12,000 and 14,000 years ago when the Wisconsin ice sheet advanced into the state (Prior, 1991). The glaciation left behind thick glacial alluvium deposits with pockets of gravel and rock outwash. The surface drainage in this ecoregion is generally poor, containing many pothole wetlands and pockets of peat and muck and with the exception of major rivers, stream valleys are generally poorly defined. Nine Eagles Lake, located in far southern Iowa, is part of the Southern Iowa Drift Plain landform region. This landform is the largest in Iowa and is characterized by steeply rolling hills and well connected drainage ways that cut deeply into the landscape.

Hickory Grove Lake is a man-made impoundment with a surface area of roughly 100 acres and a 4,035 acre watershed predominantly comprised of row-crop agriculture (85%), with perennial vegetation (mixed grass and trees) (8%) and farmstead / urban cover (3%) rounding out the majority of acres in the watershed. McIntosh Woods beach is located on Clear Lake, a natural glacial lake with a surface area of 3,891 acres and a watershed that is 13,201 acres to the outlet of the lake. The Clear Lake watershed is 48 percent water (mostly the lake itself), 31 percent row-crop agriculture, 11 percent grass / trees, and

10 percent urban / farmstead. Nine Eagles Lake has a surface area of 62 acres and is the only system where natural / perennial vegetation was the dominant land cover as almost the entire 1,100 acre watershed is within the state park boundary and land use is nearly 90 percent grass / trees and only 3 percent row-crop.

2.3. Water and Sand Sample Collection and Analysis Methods

A grab sample based monitoring network was established at each of the three systems in April of 2015. Sample points were established along three transects radiating perpendicular to the waterline across the beach and swimming zone (Figure 2-1). Sampling points were denoted alphabetically for each sampling point above the waterline (A-F, E in 2016) and were spaced at 0, 2.5, 5, 10, 15, and 20 meters from shoreline. Substrate samples were denoted numerically for each sampling point collected below the water surface at knee, waist and chest deep locations (Table 2-1). Sand substrate samples were taken from the swimming zone points (1 through 3 in 2015) at knee, waist and chest deep. In 2016, adjustments were made to the swimming zone transect points by dropping the sand substrate sample on point 3 (chest deep). Overview and yearly differences are highlighted in Table 2-1.

Table 2-1. Sampling Layout and Design Overview with Yearly Components for McIntosh Woods (MW), Hickory Grove (HIC), and Nine Eagles (NIN).

Sampling component	Naming convention	Number of transects	Samples (per transect)	Total Samples
Sand transects (2015)	Alpha (terrestrial) Numeric (lake bottom)	3	9	27
Sand transects (2016)	Alpha (terrestrial) Numeric (lake bottom)	3	8	24
Beach water transects (2015)	Numeric	3	8	24
Beach water transects (2016)	Numeric	3	9	27
Alternate transect (2016)	Numeric	1	9	9
Open lake pts (HIC, MW)	Numeric	NA	NA	5
Open lake pts (NIN)	Numeric	NA	NA	4

Water samples were taken from the swimming area points (1 through 3 in 2015) at knee, waist, and chest deep. In 2016, adjustments were made to the swimming area transect points by adding a point at ankle deep (pt. 0). Samples representing the open lake beyond the beach swimming zone started at transect point 4 (taken at the swimming zone rope) and continued through point 8 with spacing of 10 meters (except at Nine Eagles where a 6 meter interval was chosen). Sample spacing along water and sand transects closely mimics those established by recent studies in Minnesota (Ishii et.al. 2007). In 2016, an alternate transect was established along a shoreline area away from the beach (Figure 2-1). This transect was configured with same spacing (0-8) as the beach transects and was used to assess near to far shore dynamics along a non-beach shoreline. Additional *E. coli* samples were collected at various open lake locations around each system in an attempt to characterize conditions across the lake system.

Each system was visited approximately bi-weekly (with some variation for wet weather targeting) from early April to mid-October of 2015 and 2016. During sampling trips, a water or substrate sample was collected at each established point and placed on ice for transport to the State Hygienic Laboratory for analysis. Collection of sand samples along the beach was achieved by inserting a 10 cm section of one inch diameter AMS plastic cup liner into the beach sand surface, removing the top 10 cm of the sand profile. This material was deposited into a sterile sampling cup, chilled and held on ice to < 4°C for transport to lab. The 10 cm depth was selected based on previous studies showing the majority of *E. coli* activity occurs in the top 10 cm of beach sand (Alm et. al. 2003; and Wu et. al. 2017). Sand bulk densities were established for each system using the sampling tubes described above and weighing the samples before and after oven drying at 105°C for 24 hours. Duplicate samples, representing ten percent of total collection, were taken at random sampling points during each sampling event and were reviewed to detect sampling bias.

E. coli concentrations in liquid samples were analyzed using EPA method 1603 and reported as the Most Probable Number per 100 milliliter of water (MPN/ 100mL). Sand samples processed using the EPA 1603 method were first prepped for analysis by uniformly mixing total sample and removing an 11 gram subsample of substrate for mixing with 99 ml of sterilized water. The sand / water mix was agitated on a shaker tray and then liquid was pipetted into a Quanti tray for analysis. A subset of each solid (beach sand) sample was oven dried and the *E. coli* concentration of the sand samples were expressed as MPN per dry weight gram (MPN/g) of substrate.

Field observations (number of beach users, goose and shore bird counts, goose usage evidence, wave height and wind direction) were recorded upon arrival. Field parameters: temperature, turbidity, pH, conductivity, dissolved oxygen and transparency were collected at midpoint of transects adjacent to the swimming zone rope and at each open lake sampling point. Wind, solar radiation air temperature, and precipitation were gathered from nearby long term climate sites (Iowa Mesonet).

2.4. Sand Sample Collection Network

Beach sand sampling conducted during the two year project revealed consistent trends across all lake systems. Results of analysis showed that *E. coli* concentrations in beach sand generally increased with proximity to the shore line. An analysis of variation (ANOVA) on ranks showed that transect points A, B, and C were significantly higher in *E. coli* concentrations than D, E or F ($P<0.01$). Transect point B (2.5 meters from shoreline) had the highest overall median and geometric mean *E. coli* concentrations across all systems (Figure 2-2, Figure 2-3, and Figure 2-4). The nearshore gradient represented by the beach sand transect sampling points identified here are similar to other studies where near shore sands were found to contain higher bacteria concentrations than farshore samples (Ishii et. al. 2007; Whitman and Nevers, 2003; Edge and Hill, 2007).

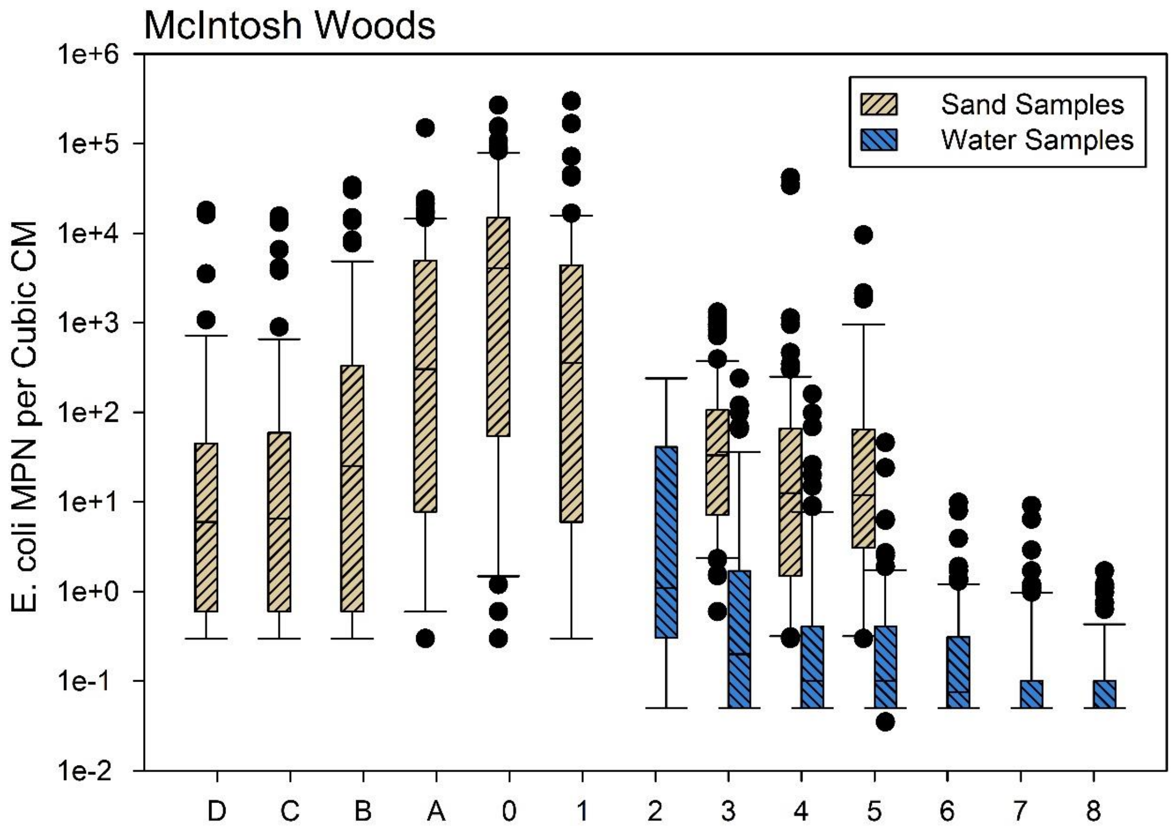


Figure 2-2. Box Plot of Sand and Water Sampling from Transects along McIntosh Woods Beach. Reported in MPN/per cubic cm. Sampling points in figure correspond to following locations in relation to shoreline: A=shoreline, B (+2.5 m), C (+5m), D (+10M), E (+15 M), F (20M), 0 (Ankle deep), 1 (Knee deep), 2 (waist deep), 3 (chest deep), 4 (swimming rope), 5 to 8 (10 m spacing beyond swimming rope)

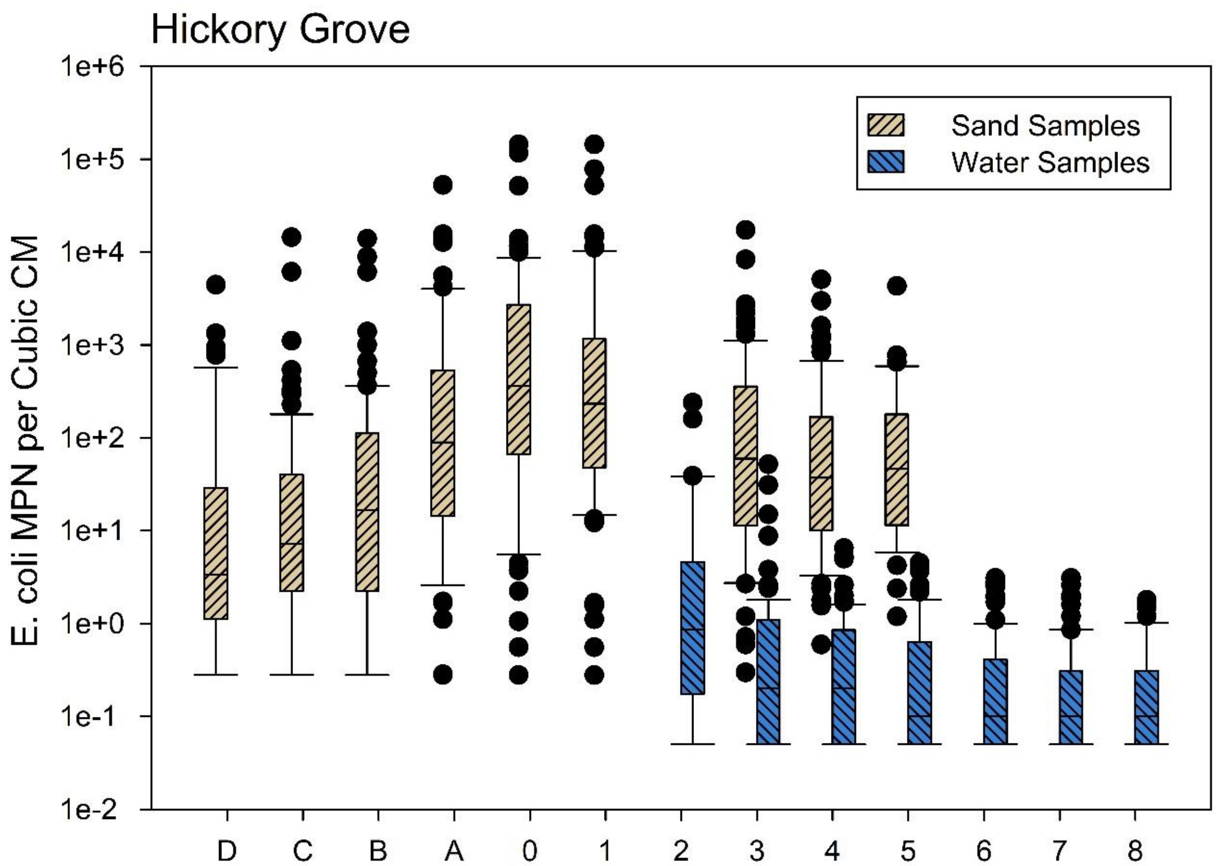


Figure 2-3. Box Plots of Sand and Water Sampling from Transects along Hickory Grove Beach. Reported in MPN/per cubic cm. Sampling points in figure correspond to following locations in relation to shoreline: A=shoreline, B (+2.5 m), C (+5m), D (+10M), E (+15 M), F (20M), 0 (Ankle deep), 1 (Knee deep), 2 (waist deep), 3 (chest deep), 4 (swimming rope), 5 to 8 (10 m spacing beyond swimming rope)

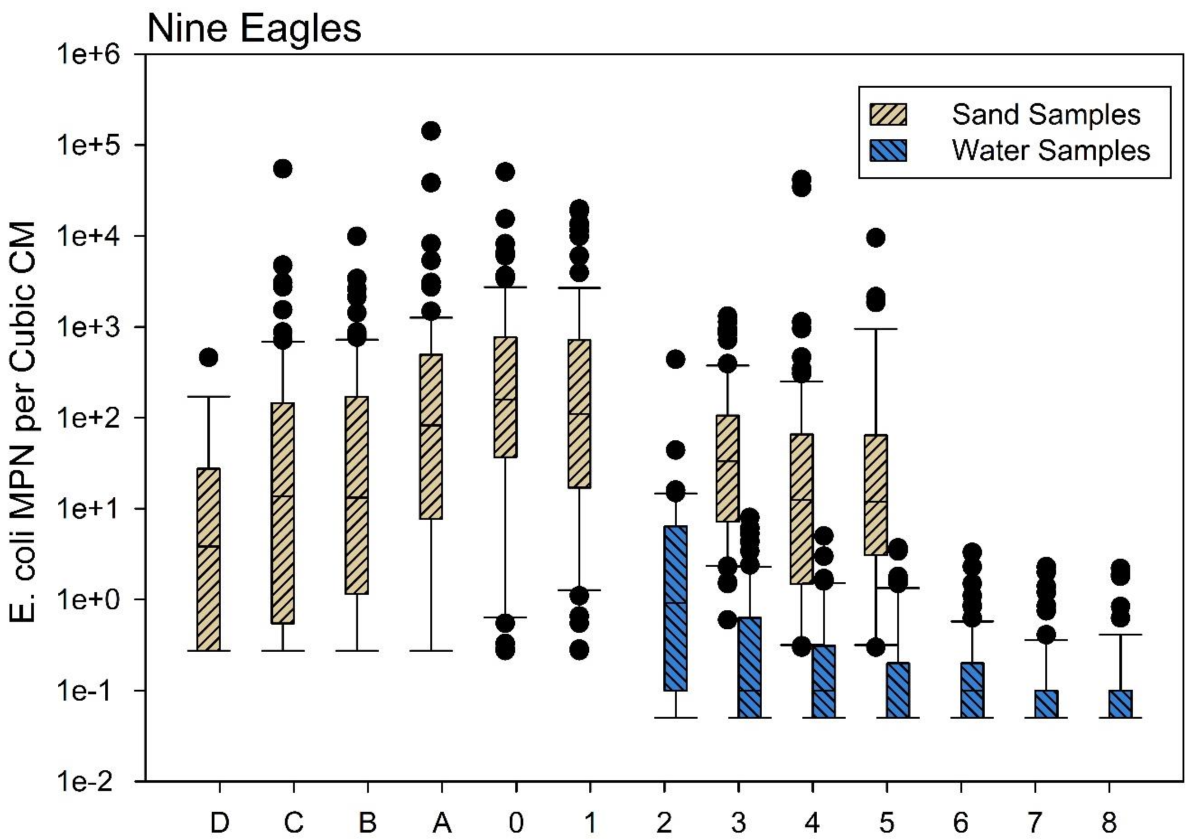


Figure 2-4. Box Plots of Sand and Water Sampling from Transects along Nine Eagles Beach. Reported in MPN/per cubic cm. Sampling points in figure correspond to following locations in relation to shoreline: A=shoreline, B (+2.5 m), C (+5m), D (+10M), E (+15 M), F (20M), 0 (Ankle deep), 1 (Knee deep), 2 (waist deep), 3 (chest deep), 4 (swimming rope), 5 to 8 (10 m spacing beyond swimming rope)

Analysis of sand moisture content yielded results that closely mimicked the *E. coli* concentration trends. The percent moisture content of beach sands increased with proximity to shoreline. Transect points D, E, and F were significantly lower in moisture than points A, B, and C at all beaches (ANOVA on Ranks $P<0.01$). Several factors like frequent rewetting of sands by wave action and shallower depth to ground water may have led to higher moisture concentrations of sands in this zone. Direct comparisons of *E. coli* concentrations to percent moisture concentrations showed positive correlations in all three systems. This relationship between *E. coli* concentrations and moisture content is consistent with numerous other studies (Desmarais et al., 2002; Heaney et al., 2014; Halliday et. al. 2015).

An additional variable that likely increases bacteria concentrations in this near shore zone was the propensity of geese to congregate at or near the waterline on the beach, concentrating goose fecal matter in this area (field observations). Researchers in Canada made similar observations, noting that geese and gull droppings were observed most frequently in the wetted sand areas adjacent to the shoreline (Edge and Hill, 2007). The overlap of source material from which to draw organisms and the relative stability (low UV light, high surface area and stable moisture content) of the nearshore beach sand environment creates a viable reservoir for harboring bacteria throughout a season (Beversdorf et al. 2007).

Table 2-2. Basic Statistics from Bacteria Sampling at Three Target Lakes McIntosh Woods (MW),Hickory Grove (HIC) and Nine Eagles (NIN).

Sampling Dataset	N	Mean	Median	St. Dev.	25th %	75th %
MW swimming zone	314	1,263	10	4,491	5	98
MW lake transects	405	26	5	90	5	10
MW open lake	120	15	5	23	5	10
MW beach sand	480	1,239	11	4,504	0.4	525
HIC swimming zone	302	348	20	2,194	5	97
HIC lake transects	435	35	10	56	5	41
HIC open lake	136	40	10	74	5	31
HIC beach sand	480	414	9.5	2,196	0.8	68
NIN swimming zone	283	225	10	2,618	5	41
NIN lake transects	400	23	5	49	5	10
NIN open lake	112	15	5	35	5	10
NIN beach sand	449	237	9	1,463	0.7	70

Water results reported as MPN/ 100mL and sand results reported as MPN/dry wt. gram

Data collected from the beach sand environment during both seasons across all sites showed a wide range of variability (Table 2-2). However, median sample E. coli concentrations were well above detection limits of (0.1 MPN/gram). This observation indicate that a bacteria community is present in the sand substrate at meaningful concentrations across a broad temporal range, a finding that is in line with other studies in North America (Ishii et. al. 2007; Whitman and Nevers, 2003). Data collected across the two sampling seasons at all three beach systems show a steady increase in sand E.coli concentrations throughout the year (Figure 2-5, Figure 2-6, and Figure 2-7). The seasonal accumulation and attenuation of E. coli from this source area observed in this study and others further demonstrates the beach sands ability to serve as a reservoir of FIB.

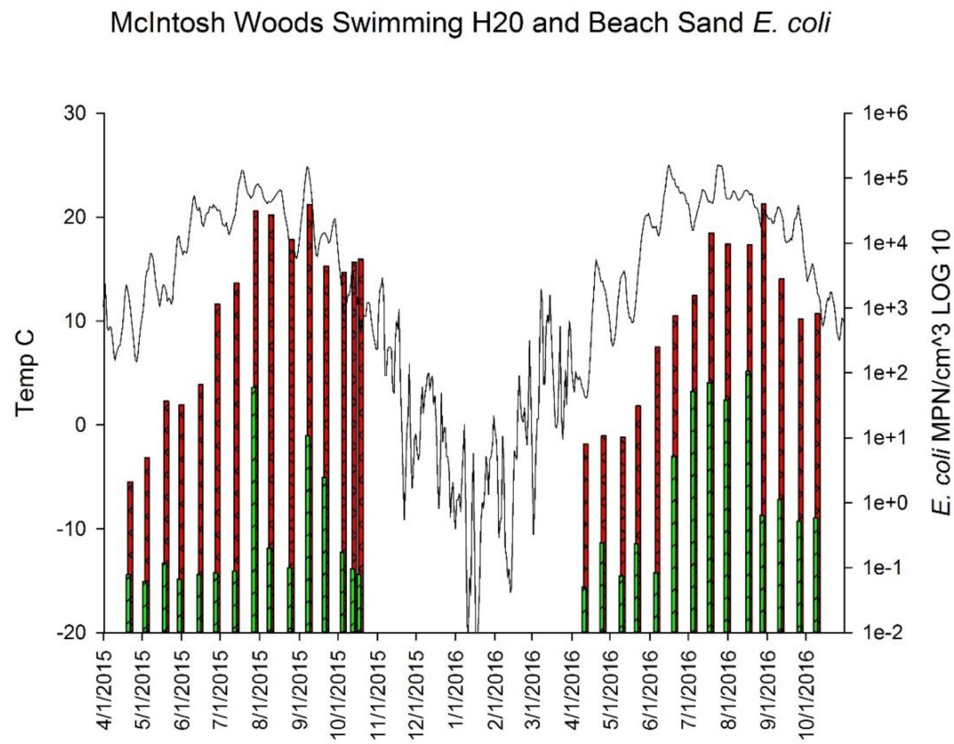


Figure 2-5. Graph of McIntosh Woods Seasonal Whole Beach Sand and Swimming Area Mean *E. coli* Concentrations, and Mean Daily Air Temperature.

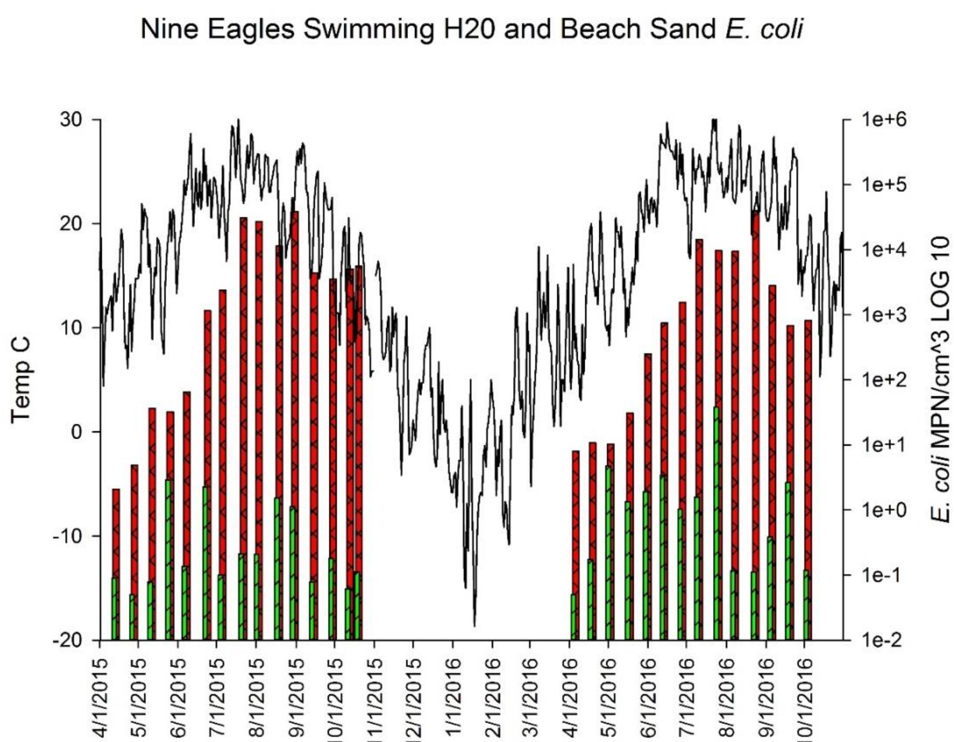


Figure 2-6. Graph of Nine Eagles Seasonal Whole Beach Sand and Swimming Area Mean *E. coli* Concentrations, and Mean Daily Air Temperature.

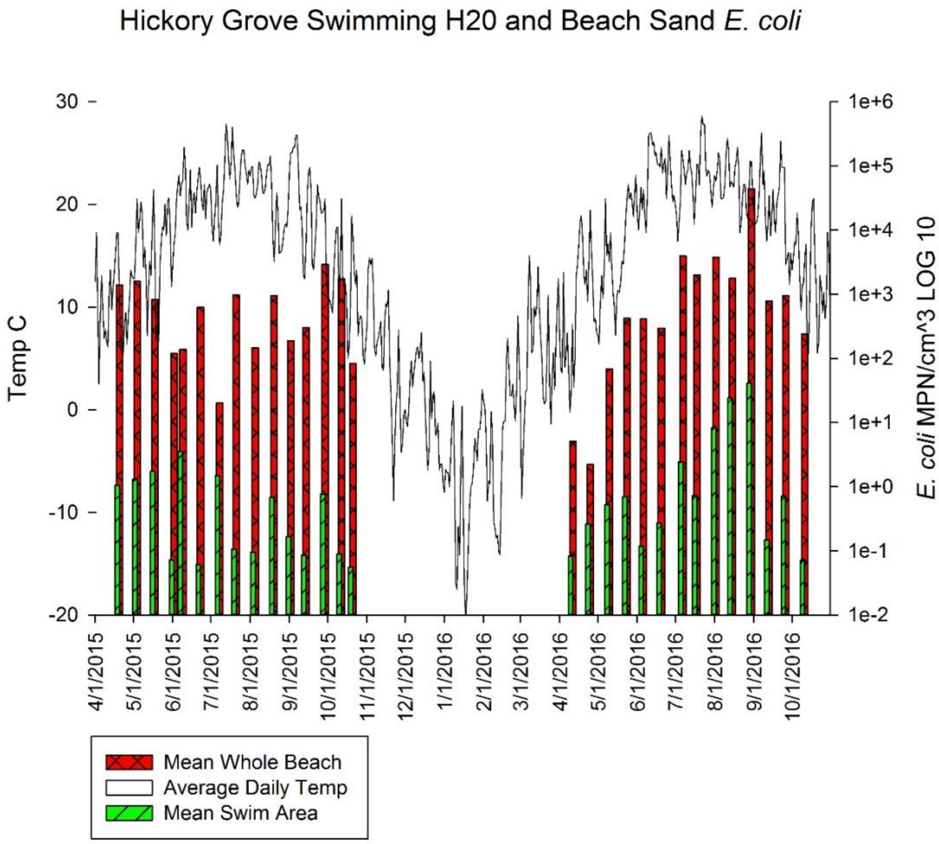


Figure 2-7. Graph Hickory Grove Seasonal Whole Beach Sand and Swimming Area Mean *E. coli* Concentrations, and Mean Daily Air Temperature.

2.5. Nearshore Swimming Zone and Lake Water Collection Network

Water sample collection in the nearshore swimming zone of all three systems showed a high degree of variability. Sample results commonly varied by several thousand MPN/ 100mL indicating that this environment was highly sensitive to changes in *E. coli* loading. While these data showed that intermittent spikes in concentrations could be quite high, the bulk of data collected showed very low *E. coli* concentrations as median dataset concentrations were at or only slightly above the detection limit of 10 MPN/ 100mL (Table 2-2). This information suggests that conditions in the recreational swimming zone can rapidly change in response to *E. coli* loading but do not maintain an elevated concentration across the season. These findings are supported by observations that during the two year sampling effort the three beach systems met recreational standards (235 MPN/ 100mL) during a majority of site visits (Table 2-3).

Table 2-3. Swimming Zone Standard Exceedance and Maximum Observed Average Swimming Zone Concentration.

Sampling Dataset	N	Met standard	Exceeded standard	Max value MPN/ 100ml
McIntosh Woods	29	21	8	10,565
Hickory Grove	29	24	5	4,090
Nine Eagles	28	23	5	3,800

As discussed earlier, intermittent spikes in concentrations at all three beach systems were observed throughout the project. These spikes resulted in a number of days where the swimming environment exceeded recreational standards and triggered an advisory condition (Table 2-3). These elevated conditions were largely driven by higher readings closer to the shoreline as sampling data collected along transects radiating out from the shoreline into the lake (Figure 2-2, Figure 2-3, Figure 2-4, and Figure 2-8) uncovered an association between E. coli concentrations and proximity to shore.

Sampling points at the ankle deep location along transects at all beaches were higher in *E. coli* concentrations than all other sampling points in the lake (ANOVA on Ranks P<0.001). This near to far shore association was particularly strong along the McIntosh Woods beach transects, where points 0, 1, 2, and 3 (ankle, knee, waist, and chest deep) were significantly higher than each point positioned farther from shore. These observations related to concentrations and shoreline proximity are in line with observations in other recent studies (Enns et al.,2012; Ishii et. al. 2007; Whitman and Nevers, 2003).

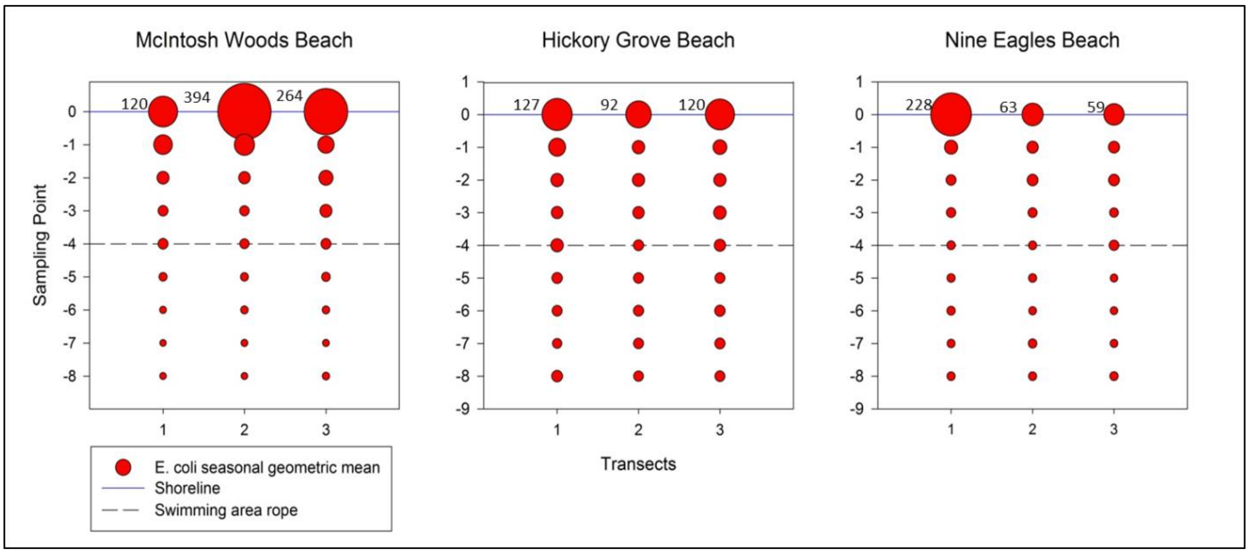
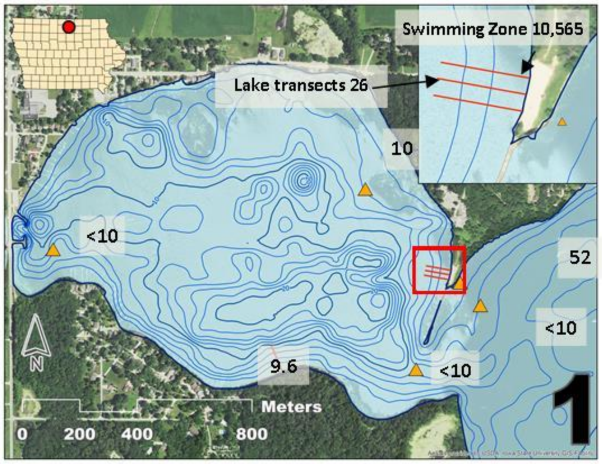
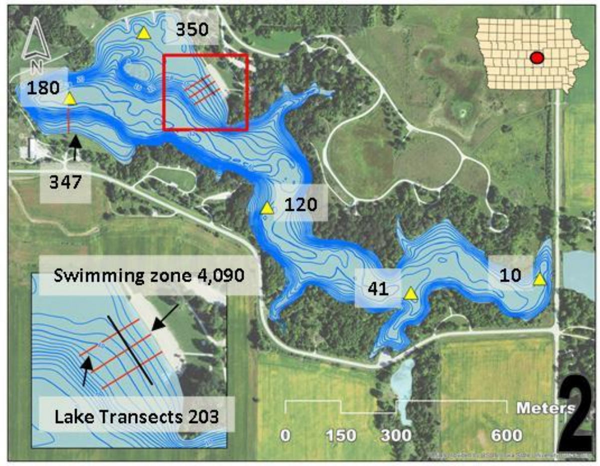
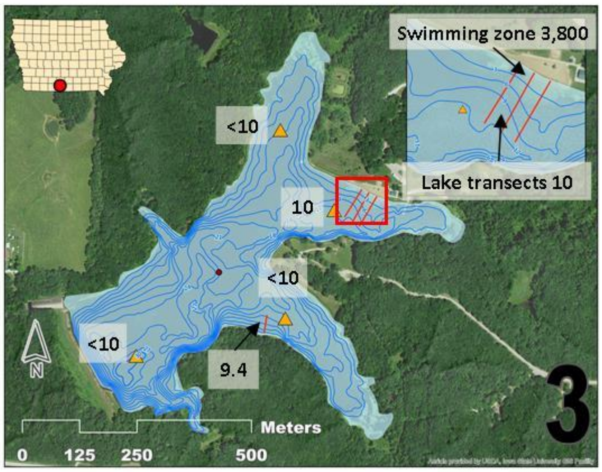


Figure 2-8. Bubble Plot of E. coli Sampling at Lake Transects Across Project Beaches Reported as MPN/ 100mL.

Data aggregated across the two sampling seasons also showed that E. coli concentrations varied significantly between swimming zone, lake transects and open lake sampling locations among all lakes (ANOVA on Ranks p<0.001) with levels decreasing respectively. Not only were the open lake sampling points significantly lower in E.coli concentrations than the swimming zone but the timing of spikes in concentrations observed in the datasets showed a clear disconnect between the two. The highest overall mean open lake concentration observed in each of the systems occurred on days where mean swimming zone values fell well below the water quality violation threshold of 235 MPN/ 100ml. Additionally, the highest overall swimming zone concentrations were observed on dates where a majority of open lake values were below the detection limit of 10 MPN/ 100mL on two of the three systems (Figure 2-9).







Lake/Beach System	Swimming zone mean MPN /100ml	Open lake Mean △ MPN /100ml
(1) McIntosh Woods 8-18-2016	10,565	15.4
(2) Hickory Grove 8-30-2016	4,090	140.2
(3) Nine Eagles 7-26-2016	3,800	6.3

Figure 2-9. Maps of Maximum Swimming Zone Event Mean E. coli Concentrations and Corresponding Open Lake Results.

Discrepancies in the timing and magnitude of peak *E. coli* concentrations represented in Figure 2-9 and highlighted by statistical analysis show a clear disconnect between conditions at the recreational swimming beach and the larger lake system. Data collected along alternate shoreline transects established during the 2016 monitoring season at each lake also demonstrated a divergence with the swimming zone transects. A comparison of beach zone transects to alternate transects uncovered significantly lower *E. coli* concentrations on the alternate transects for Nine Eagles Lake and McIntosh Woods Beach ($p<0.01$) but not at Hickory Grove Lake ($p = 0.41$). The differences observed on Nine Eagles and McIntosh Woods beaches indicate that the shoreline dynamics that lead to elevated *E. coli* concentrations along the beach shoreline did not manifest along these alternate transects.

The lack of differences uncovered in the Hickory Grove Lake comparisons may have had to do with the open park environment in this system. The alternate transect on this lake was established along a shoreline, which was routinely mowed and sloped steeply to the water. This open park-like area was frequently observed being used as a grazing / loafing area for 30 to 60 geese (field observations). The presence of source material may have allowed for the near to far shore dynamics observed in the swimming zone to manifest at the alternate transect in this system. Even with this source in close proximity to the alternate transect there were only two occasions where near shore sampling along this transect resulted in an average concentration exceeding 235 MPN/ 100ml.

2.6. Nearshore Swimming Zone and Beach Environment Relationships

As previously discussed an analysis of lake and swimming zone water collection datasets showed a clear disconnection in *E. coli* concentration trends. Additionally, in a majority of systems across a range of collection conditions the nearshore to *E. coli* concentration dynamics observed at the swimming beach did not manifest along non-beach shorelines. An analysis of association (Spearman Rank Order Correlation) between near shore beach sand *E. coli* concentrations and mean swimming zone water concentrations uncovered positive relationships. Results of the analysis showed that swimming zone *E.coli* concentrations increased as beach sand *E. coli* concentrations increased.

Previously highlighted statistical associations coupled with the major disparities in *E. coli* concentrations observed between beach sands and water lend evidence in support of the near shore beach environment serving as a major contributing source to elevated bacteria conditions in the swimming zone. These observations are supported by recent investigations of beaches along Lake Ontario, which indicated that near shore beach sands accumulate and maintain bacteria across the season, serving as a driver for water quality violations during rainfall or wave driven wash off events (Wu et. al. 2017).

The degree to which this beach sand reservoir of *E. coli* can impact the near shore swimming environment is probably best highlighted by observed discrepancies in concentrations. Direct comparisons between water concentrations and sand concentrations were performed using the EPA criterion assuming that MPN/cm^3 sand is roughly equivalent to MPN/mL of water that has been used in previous research efforts (Ishii et. al., 2007; Whitman and Nevers, 2003). Results of these comparisons showed that median sampling event *E. coli* concentrations in the area along the beach shoreline (transect points A, B, and C) ranged from 3 to 86,565 times higher than median swimming zone concentrations (Table 2-4 and Figure 2-2, Figure 2-3, and Figure 2-4). The discrepancy in concentrations between sand and water samples is similar to observations noted along Northern Minnesota beaches where it was reported that average sand *E. coli* concentrations were upwards of 4,980 times higher than water concentrations (Ishii et. al., 2007).

Table 2-4. Nearshore Sand E. coli Concentrations Represented in Magnitude of Difference From Swimming Zone Concentrations.

Sampling Dataset	N	X higher concentration AVG	X higher concentration MIN	X higher concentration max
McIntosh Woods	29	13,800	10	86,600
Hickory Grove	29	2,800	7	16,700
Nine Eagles	28	1,900	3	8,200

Calculations of standing stock *E. coli* bacteria quantities in the beach sand and swimming zones echo the discrepancy in magnitude observed in concentrations. The total quantity of *E.coli* in the swimming zone of each system only represented a small percentage of that observed in the beach sand. Median percentages of swimming zone populations ranged from one to six percent of what was observed in the beach sand area (Table 2-5). Mobilization of only a small percentage of the bacteria present in beach sands on these systems is required to push the swimming zone into impairment status. It was estimated that delivery of as little as 0.3 percent (Table 2-5) of the bacteria in the beach sands could result in the impairment of the near shore swimming environment. This observation underlines how impactful the condition of this nearshore sand environment can be on the recreational swimming zone at beaches around the state.

Table 2-5. Swimming Zone E. coli Population Expressed as Relative Percent of Beach Sand Total Population From Whole Sampling Data Set and During Swimming Zone Impairment Conditions (>235 MPN/ 100mL).

Sampling Dataset	N	Median Swimming Zone %	MIN Swimming Zone % >235 MPN/ 100ml
McIntosh Woods	29	6%	1.2%
Hickory Grove	29	1%	0.6%
Nine Eagles	28	3%	0.3%

2.7. *E. coli* Transport Mechanism and Factors Affecting *E. coli* Concentration

The nearshore beach sand environment clearly represents the major contributing source of *E. coli* to the recreational swimming zone on the three study sites in this project. Many mobilization pathways are possible when the contributing source is in such tight proximity to the environment of concern. Two major pathways (precipitation and wave action) shown to be of importance in multiple research efforts were used as a guide to assess mechanisms on our study sites.

Precipitation driven wash off has been shown to be an important delivery method in other swimming beach sand and water research efforts (Heaney et al. 2014), however analysis of this obvious mobilization pathway provided weak evidence supporting the importance of this pathway. Spearman Rank Order Correlation and multiple linear regression models were run for the one, two, and seven day trailing precipitation vs. swimming zone, lake transect, open lake and beach sand sampling. Results from this analysis uncovered a lack of association between one, two or seven day precipitation and swimming zone *E. coli* concentrations and sand *E. coli* concentrations in almost every comparison. The Nine Eagles swimming zone and lake transects showed association with the seven day trailing precipitation values. Elevated swimming zone and beach sand *E. coli* concentrations were observed during both wet and dry conditions at all three systems across both sampling seasons. This observation is in line with recently completed studies on the Hickory Grove system, which found similar patterns of *E. coli* concentrations in the beach swimming zone and a lack of statistical correlation between rainfall and bacteria counts (Gali and Soupir, 2015).

This lack of association between precipitation and bacteria concentrations indicates that numerous delivery and condition based mechanisms are at play in these beach / lake environments. Sampling conducted as part of this study spanned from early April to mid-October in both sampling years. Samples collected in the early spring showed a pattern of lower bacteria concentrations in each of the systems. This was especially pronounced at the northern most beach system, McIntosh woods (Clear Lake), where mid to late season sand *E. coli* concentrations were several orders of magnitude larger than those observed in the spring of the year (Figure 2-5, Figure 2-6, and Figure 2-7). Recent studies in Minnesota indicate that lower temperatures in the spring of the year limit accumulation, survivability and growth of bacteria in the nearshore beach sand environment (Ishii et. al., 2007). Wash-off potential may be limited during these early season conditions as the reservoir of bacteria in the beach sands are not well established during this timeframe.

Onshore wind and associated wave action, an important delivery mechanism identified in multiple studies, has been shown to correlate with increased near shore sand wash-off potential and elevated nearshore water *E. coli* concentrations (Kinzelman et. al. 2004; Haack, et. al., 2003; Skalbeck et al, 2010; Heaney et. al. 2014; and Wu et al. 2017). Sand transect sampling consistently showed that near shore sands (pts A and B) contained the highest *E. coli* concentrations on all three systems, indicating an elevated potential of delivery from this source through this mechanism. Previous research has shown that the interaction of wave action driven by onshore winds and the associated washoff / ground water seepage mines the near shore sands of bacteria, pulling the *E. coli* from this near shore sink into the near shore water environment (Edge and Hill, 2007; Whitman and Nevers, 2003; Wu et. al. 2017). A signature of this wash zone depletion is represented well by transect sampling points A and B (Figure 2-5, Figure 2-6, and Figure 2-7). Point A was consistantly lower in *E. coli* concentration than point B indicating that the removal / disruption process driven by washzone dynamics seen in other studies may be at play in these systems.

An analysis of the average wind speed multiplied by percentage of hours of onshore wind for the trailing 1, 2, and 3 days uncovered no association between this delivery mechanism and corresponding swimming zone bacteria concentrations. Similar to the analysis of precipitation based delivery, the datasets in this study could not statistically define an overriding association between wind driven wave action and elevated swimming zone bacteria concentrations. This lack of direct association further indicates that numerous pathways of delivery are at play in these systems, all of which may activate under various conditions masking statistical associations.

An overlapping factor of concern is the presence of geese and other shore birds in the nearshore beach environment. Goose usage (tracks and or fecal matter) was observed on 79, 86, and 90 percent of all sampling trips to Nine Eagles, Hickory Grove, and McIntosh Woods respectively. Active goose and gull loafing was frequently observed across all sites during the study period. Goose defecation was concentrated in the near shore sands (within 5 meters of shore line) and along the turf grass areas immediately adjacent to the beach (field observations). Shore bird usage of the beach environment has long been identified as a potential source of fecal contamination to nearshore swimming waters (Ishii, et. al. 2007; Lu, et. al., 2011; Edge and Hill, 2007; Haack, et. al., 2003; and Alm et. al. 2003).

Recent investigations of shore bird impact on a Canadian beach showed that over 60% of samples taken from the near shore sands and ankle deep water were positive for avian specific bacteria (Edge and Hill, 2007). Additional investigations in Canada showed positive relationships between gull usage observations and detections of gull specific genetic markers (Lu, et. al., 2011). This association between field observations and positive identification provides evidence that the shore bird populations observed on the three beach systems in this study likely serve as a continuous source of fecal contamination, feeding the near shore sand and water environment with bacteria throughout the season.

2.8. Conclusions

There was a broad range of evidence indicating that swimming zone bacteria concentrations are disassociated with watershed loading and open lake processes. Analysis of sampling datasets point toward beach proximate *E. coli* loading from a combination of shore birds, and the nearshore sand reservoir as being the dominate sources of bacteria influencing swimming zone concentrations. This finding was true across a range of lake sizes, natural and man-made systems and across two major landform regions within Iowa. Support for these findings from a range of upper Midwestern and Canadian systems were found in recent literature as subsequently highlighted throughout this document.

The data collection and analysis could not identify an individual mechanistic pathway singularly responsible for delivery of bacteria loads to the nearshore swimming beach environment. The evidence collected as part of this research indicates multiple pathways of delivery are involved in the loading process. Near shore sand bacteria concentrations, in some cases thousands of times higher than near shore swimming water, were observed across all systems. As previously highlighted in recent literature, the mobilization of this source material through wind driven wave wash-off and/or precipitation based runoff are two important delivery pathways. A confounding issue impacting statistical associations with these two pathways was the periodic presence of large shore bird populations in the beach area. Direct defecation / delivery from these bird flocks had the potential to confound statistical analysis of pathway importance. As few as five geese have been estimated to result in beach impairments at the Hickory Grove Lake system without activating a mobilization pathway (Gali and Soupir. 2015). The influence of these bird populations on nearshore water concentrations could have reduced the sensitivity of our analysis on other mobilization pathways.

Reductions in both the quantity of *E. coli* present in the near shore beach environment and the rate / effectiveness of mobilization will be critical to reducing the frequency of elevated swimming zone *E. coli* concentrations. As resource managers seek to reduce bacteria levels at swimming beaches it may be helpful to identify the specific sources of the bacteria through genetic analysis. The identification of these sources will help researchers and managers identify critical pathways and reservoirs in the system that could be augmented or reduced in the management of the beach environment.

3. General Lake and Environmental Information

3.1. Problem Identification

As of the 2016 impaired waters list (303(d)) there are 34 significant publicly owned lakes in the State of Iowa that do not meet water quality standards (WQS) and are not fully supporting Class A1 (primary contact recreation) uses due to the presence of high levels of a fecal indicator bacteria (FIB) called *Escherichia coli* (*E. coli*). High *E. coli* levels in a waterbody can indicate the presence of potentially harmful bacteria and viruses (also called pathogens). Under Iowa Administrative Code (567 Iowa Administrative Code, Chapter 61, (IAC)), waterbodies are impaired for *E. coli* if the geometric mean (GM) of all samples exceeds 126 orgs/ 100 mL of water or a sample maximum value of 235 org/ 100 mL. This standard is only applicable during the recreational season, defined as March 15 through November 15.

Water quality samples collected and analyzed as part of the Ambient Water Quality Monitoring and Assessment Program that resulted in the waterbodies being impaired were collected from the swimming zones near recreational beach areas. Additional samples collected, although limited, of the open lake did not show a pattern of non-compliance with water quality standards. From comparisons of samples it was reasonable to assume that the source of the impairment was from the near shore beach environment and not the other sources in the watershed.

In 2015 the Iowa DNR started a two year water quality study to study and assess the relationships between the nearshore beach environment and open lake conditions. Additional samples were collected in the open lake and at the near shore beach area at Hickory Grove Lake, McIntosh Woods State Park, (Clear Lake), and Nine Eagles Lake. The results of this study demonstrate that that the source of the impairment is not from watershed but from the nearshore beach environment and that levels of *E. coli* drop off significantly outside the swimming zone (chest deep water). For a more detailed discussion on the study see Chapter 2 of this WQIP.

As a result of the study, each individual TMDL will focus on the nearshore beach environment as the sole source of bacteria driving the impairment. Further action to be considered as a result of this study is to give each beach area its’ own waterbody ID and decouple it from the lake.

Problem Statement

Water quality assessments indicate that primary contact recreation is either “not supported” or only “partially supported” in these lakes due to high levels of fecal indicator bacteria (*E. coli*) that violate the state’s WQS. The significance of the impairments noted in the assessments is that desirable recreational activities, such as swimming and wading, are not supported by existing water quality in the impaired waterbodies. As a result of these findings, the Federal Clean Water Act requires that TDMLs for *E. coli* be developed for all the impaired waterbodies.

General Description of the Pollutants

Fecal material from warm-blooded animals contains many microorganisms. Some of these microorganisms can cause illness or disease if ingested by humans. The term pathogen refers to a disease-causing microorganism, and can include bacteria, viruses, and other microscopic organisms. Humans can become ill if they come into contact with and / or ingest water that contains pathogens.

It is not practical to test water for every possible pathogen that may be present – there are simply too many different kinds of pathogens. Instead, water quality assessments typically test for an organism such as total coliform, fecal coliform, or *E. coli* to indicate the presence of pathogens from fecal material.

E. coli is a type of fecal coliform, and its presence theoretically correlates with illnesses that result from human exposure to water that is contaminated with fecal material (Mishra et al, 2008). It should be noted that not all types of *E. coli* cause human illness; however, the presence of *E. coli* indicates the likelihood that pathogens are present. For the purposes of this TMDL, *E. coli* is used as the fecal indicator bacteria. The two primary reasons for using *E. coli* are: (1) the EPA currently considers *E. coli* to be the preferred bacterial indicator, and (2) Iowa's WQS are written for *E. coli*.

Waterbody Designations and Descriptions
In February 2008, changes to Iowa's surface water classifications were approved by the EPA and all waterbodies were presumed to be Class A1, primary contact recreation until a use attainability assessment could be completed and approved by the EPA. Stream designations are defined and classified for protection of beneficial uses in the Iowa Administrative Code (IAC) 567-61.3(1).

Beneficial uses as defined in the IAC 567-61.3(1) are cited below.

- 567-61.3(1)(b)(1) Primary contact recreational use (Class "A1"). Water in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing, and water contact recreation canoeing.
- 567-61.3(1)(b)(7) Lakes and wetlands- (Class "B(LW)"). These are artificial and natural impoundments with hydraulic retention times and other physical and chemical characteristics suitable to maintain a balanced community normally associated with lake-like conditions.
- 567-61.3(1)(b)(10). Human health (Class "HH"). Waters in which fish are routinely harvested for human consumption or waters both designated as a drinking water supply and in which fish are routinely harvested for human consumption.

Designations and descriptions for individual impaired waterbodies will be discussed in the respective sections of this WQIP.

Data Sources and Monitoring Sites
The primary sources of water quality data used in the development of this WQIP are water quality data collected by the Iowa DNR as part of the State's Ambient Water Quality and Monitoring Program. These data consist primarily of grab samples collected between 1999 and 2018. The following list summarizes sources of additional data used for this WQIP:

- Sampling Data collected by Iowa DNR as part of the States' Ambient Water Quality and Monitoring Program.
- Lake data collected by Iowa DNR Watershed Improvement Section for the purpose of TMDL development.
- Precipitation data from the National Weather Service Cooperative Observer Program (NWS COOP) (IEM, 2015).
- 10-m Digital Elevation Model (DEM) available from DNR GIS library.
- U.S. Department of Agriculture National Agricultural Statistics Service Cropland Data Layer (USDA CDL) reflecting 2014 conditions.
- Aerial images (various years) collected and maintained by Iowa DNR.
- Bathymetric data layer maintained by the Iowa DNR Fisheries

3.2. TMDL Target

Selection of Environmental Conditions
The critical period for the impairment occurs in the recreational season of March 15 to November 15.

Pollutant Loading Capacity
Attainment of the WQS to fully support primary contact recreation requires that the GM for *E. coli* concentrations be no greater than 126 orgs/ 100 mL and the single sample maximum (SSM) be not greater than 235 orgs/ 100 mL (Iowa Administrative Code 567, Chapter 61, Water Quality Standards for Class A1 uses). The methods used to develop the *E. coli* TMDLs for the lakes are based on the assumption that compliance with the SSM will coincide with attainment of the GM targets set forth in this TMDL. Therefore, the loading capacity of each TMDL is the maximum number of *E. coli* organisms that can be in the lake while meeting the SSM criterion of 235 orgs/ 100 mL.

Decision Criteria for WQS Attainment
Seasonal load curves (SLCs) were constructed using a near shore beach volume (NSBV) and the SSM criterion to quantify the loading capacity of each impaired waterbody, in terms of load (orgs/ 100 mL), across the three seasons of spring, summer, and fall.

WQS will be attained in the impaired waterbody when the monitored *E. coli* concentration meets the SSM criterion of 235 orgs/ 100 mL during the recreational season of March 15 – November 15.

3.3. Pollution Source Assessment

Ambient samples collected at beach areas are used to assess the water quality of the lake. To show that the beach environment is the only source contributing to the impairment a study was conducted by the Iowa DNR that included collecting samples in the open lake, in the near shore beach environment, and in the beach sands. Based on the study and the data presented in Chapter 2, the only significant source of the impairment comes from the beach sand environment. The other nonpoint source contributions to the impairment are insignificant. Samples collected during the 2015 and 2016 study show some single samples exceed the geometric mean of 126 orgs/ 100 mL and the SSM of 235 orgs/ 100 mL however, there is insufficient levels of *E. coli* to result in impairment.

Existing Loads
Samples collected during the recreational season (Mar 15 – Nov 15) were grouped into three seasons spring (March 15 – May 22); summer (May 23 – September 7); and fall (September 8 – November 15). Grouping the seasons in this manner allows us to include the Memorial Day and Labor Day weekends in any given year in the summer season, which is the highest recreational use period. The 90th percentile of observed *E. coli* concentrations within each season was selected as the existing concentration for each season. *E. coli* loads were estimated by multiplying existing concentrations (orgs/ 100 mL) by the near shore beach volume (NSBV).

Using an approach that resembles the framework of a load duration curve, the measured concentrations were plotted against the spring, summer, and fall seasons. A load duration curve plots mass loadings versus flow. This plots concentration versus month. In the load duration curve the concentration is multiplied by the average daily flow rate, which changes from day to day. In this approach, it is assumed that the NSBV is constant, although there may be variations in the NSBV from year to year depending upon drought or high precipitation years. Because it is assumed that the NSBV is constant it is possible to list *E. coli* as a concentration and not a mass loading. Figure 3-1 is a seasonal load plot for the Hickory

Grove Park Beach and is presented here as an example of the format of the seasonal load curve used throughout this WQIP.

The existing load during each season was the 90th percentile of observed *E. coli* concentrations. It is assumed that if the necessary reduction in *E. coli* concentrations is attained it will meet other criterion also (EPA, 2007).

Each diamond represents an observed *E. coli* concentration sample collected throughout the sampling period. Blue-shaded diamond (◆) indicate samples collected in the spring (March to Late May), green-shaded diamonds (◆) indicate samples that were collected in the summer (Late May to Early September) and gray shaded (◆) diamonds indicates samples that were collected in the fall (Early September to November).

Data points with a red X (X) indicate where *E. coli* concentrations exceeded the quantitative limits of the analysis. Typically this value was 24,000 orgs/ 100mL, however in some cases the limit could be 2,419.6 orgs/ 100 mL. In these cases, the value used in the calculations was the quantitative limit value.

Data points outlined with a red diamond (◇) indicate samples that had *E. coli* concentrations below the reporting thresholds. Typically this value was 10 orgs/ 100 mL, however in some cases the limit was 1 org/ 100 mL. In these cases, the value used in the calculations was the average between zero and the reporting threshold value.

Seasonal load curves show the existing concentration (90th percentile) within each season (either a red or black dotted line) and the target concentration (green dashed line). The difference between these two is the departure from the loading capacity.

A red dashed line indicates that there were a sufficient number of samples that exceeded the SSM criterion that resulted in an assessment of not fully supporting designated uses. A black dashed line indicates that there were an insufficient number of samples exceeding the SSM criterion to assess the waterbody as not fully supporting designated uses. In the Methodology for Iowa's 2016 Water Quality Assessment, to be assessed as "fully supporting" the following conditions should be met: (1) the recreation season geometric means of at least seven *E. coli* samples collected during any of the three recreational seasons (March 15 to November 15) in the current data gathering period (should not exceed the respective water quality criterion of 126 *E. coli* organism per 100 mL of *E. coli* and (2) the percentage of combined number of samples collected over the three recreation seasons that exceeds Iowa's SSM allowable density of 235 *E. coli* organism per 100 mL should not be significantly greater than 10%.

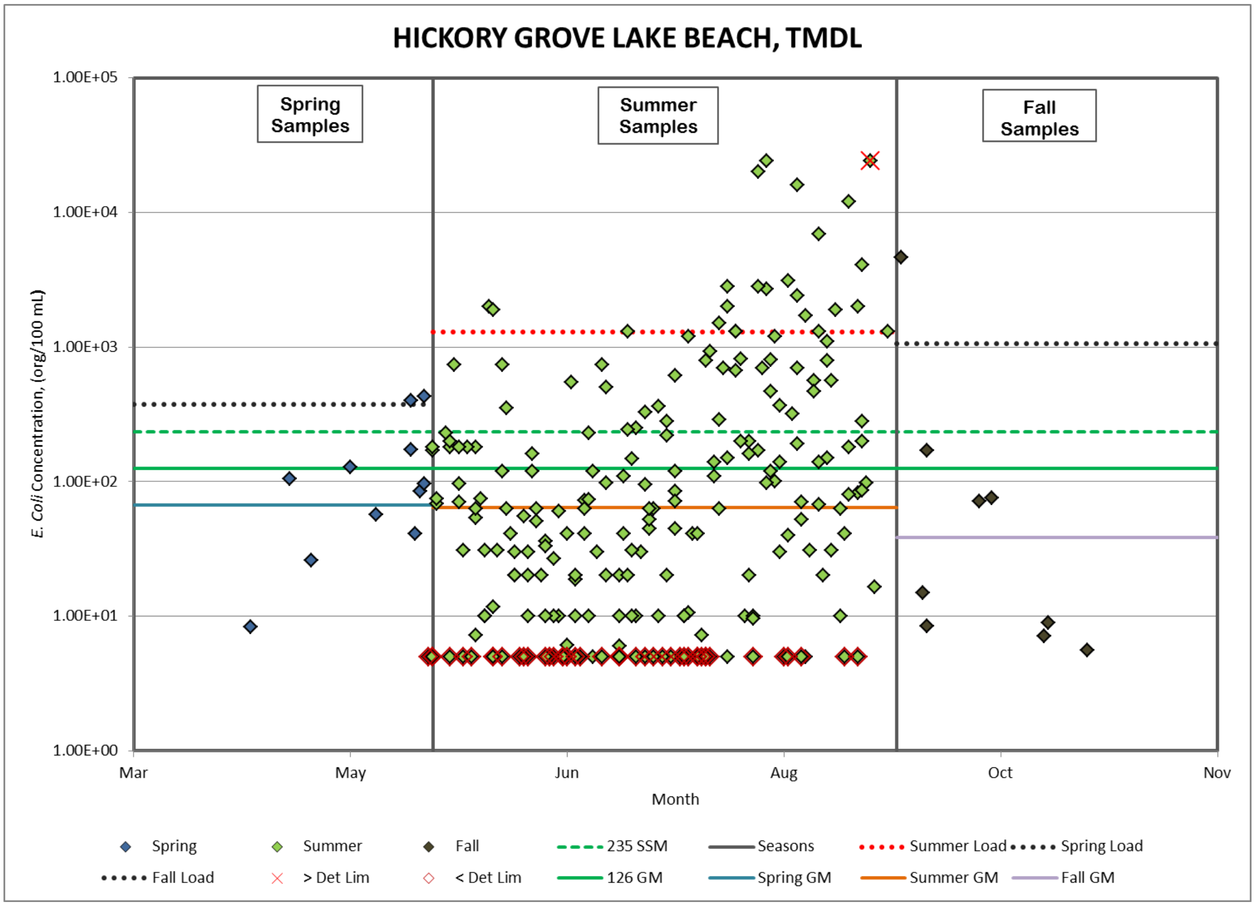


Figure 3-1. Seasonal Load Curve for Hickory Grove Lake Beach.

Near Shore Beach Volume (NSBV)

The mass loading for each lake was developed around the Near Shore Beach Volume (NSBV). The NSBV is the volume of water adjacent to the beach and is the volume of water within the swimming zone of the lake. This volume is defined as the area adjacent to the beach extending perpendicular from the shore line out to a depth of 4 feet, plus 1 meter horizontal distance, and running the entire length of the beach front. The NSBV was determined using tools found in ArcMAP along with bathymetric and DEM data maintained by the Iowa DNR. It is assumed that the lake level is constant from year to year, consequently the NSBV is constant also. Mass loading is the product of NSBV and concentration.

For future planning purposes it may be necessary to estimate *E. coli* loads in the swimming zone based on the results of sand samples. In order to accomplish this an *E. coli* transport efficiency was determined. This efficiency is the ratio of the *E. coli* load in the swimming zone to the *E. coli* load in the beach area.

Sand samples were collected from beach areas at 8 lakes between 2015-2018. Table 3-1 lists the beaches sampled, year(s) sampled, and total number of samples collected at each beach.

Table 3-1. Samples Collected.

Lake/Beach	Year(s) Collected	No. of Sampling Dates
Hickory Grove	2015-2016, 2018	32
McIntosh Woods (Clear Lake)	2015-2016, 2018	35
Nine Eagles	2015-2016	28
Brushy Creek	2017-2018	13
MacBride	2017-2018	13
Prairie Rose	2017	5
Ahquabi	2017	5
Keomah	2017	4

Ratios were calculated for each day samples were collected. Using the full data set the 75th percentile value of 0.178 was selected as the transport efficiency.

This value is strictly for planning purposes and not to be used in lieu of actual field data collected.

3.4. Reasonable Assurance

Under current EPA guidance, TMDLs that allocate loads to both point sources (WLAs) and nonpoint sources (LAs) must demonstrate reasonable assurance that required load reductions will be implemented. For point sources, reasonable assurance is provided through NPDES permits. Permits include operation requirements and compliance schedules that are developed based on water quality protection. For nonpoint sources, allocations and proposed implementation activities must satisfy four criteria:

- They must apply to the pollutant of concern
- They will be implemented expeditiously
- They will be accomplished through effective programs
- They will be supported by adequate water quality funding

3.5. Implementation and Management Plan

A general approach to preventing, mitigating, and remediating excess bacteria load will be necessary to reach TMDL targets for impaired beaches. This approach may be tailored to site specific conditions on beaches described in this document, but a brief overview of options available will be valuable for future implementation of best management practices statewide.

Once the *E. coli* violations observed in the recreational swimming zone have been isolated to the nearshore beach environment, focus should shift to management of this environment. As laid out in Chapter 2 there are three dominant pathways by which *E. coli* can be delivered to the swimming zone in these systems; precipitation driven wash off, wind driven wave action, and direct deposition. Any management actions taken should be specifically designed to either reduce these pathways or to deplete the pool of available *E. coli* bacteria in the near shore environment.

The TMDL development process for each system will highlight some source reduction targets and may provide guidance on the relative importance of individual delivery pathways. The first phase of management planning should refer to this document and use the recommendations contained within as a general base line for guidance. From here local staff may want to enhance what is known about the specific beach system before adopting a management plan.

An inventory of current management techniques should be completed. For instance, is the beach groomed, if so what tool / technique is deployed, how often, and in what areas? This information can be used to show where staff and monetary resources are being deployed and will help identify areas of management that can be augmented or enhanced as planning moves forward. It is possible that redirecting staff time with a more focused approach could provide benefits to the system at minimal additional cost / time.

The next step in this process should be a baseline assessment of the three major pathways of concern (some of this information may be available from TMDL assessment). Examples of this assessment are as follows: Local park / beach staff should highlight areas of concentrated runoff that enter the beach sand area and wash down to the lake. These areas of runoff could be treated or diverted to avoid washing *E. coli* from the beach sands down into the lake water. Noting areas of concentrated goose and shore bird loafing could allow staff to direct management to specific areas either removing the fecal matter or targeting reduced loafing activities. Once local information like this has been collected managers can take a comprehensive look at the data and begin highlighting areas of concern.

Taken together, the system observations, management inventory, and TMDL guidance can be used to inform the following potential management actions:

- Raking activities / grooming strategies that remove fecal material
- Reduce goose usage of the beach environment
    - Involves reducing comfort level of geese
        - Predator decoys frequently moved
        - Strobe lights
        - Increased staff harassment especially during minimal public use times
- Plant a strip of prairie grasses along the shoreline.
    - This will reduce the ease of access to the water for geese and act as a filter trapping material entrained in runoff coming down to the lake
- Where applicable, install a gutter system on the picnic shelter controlling roof runoff at one point
    - Roof water could be diverted into a rain garden or other treatment feature
    - Roof water could be piped underground directly to the lake eliminating wash off of *E. coli* from grass and beach area
- Manage parking area runoff
    - Ideally accomplished using a rain garden or other infiltration based practice
        - Reduces *E. coli* wash off potential and reduces management cost on beach

This general example highlights how staff can quickly identify potential source areas and develop management techniques that work toward reducing the magnitude of *E. coli* sources and the interrupting the pathways of delivery to the swimming zone. In developing a monitoring strategy each system will have its own subset of issues that will need to be addressed. The overarching concern in all systems will be the reduction of *E. coli* bacteria standing stocks and reducing the efficiency of delivery. The assessment of each system will be critical to management success as the relatively small capture shed associated with the impairment and unique local conditions preclude the adoption of a standardized management scheme.

3.6. Future Monitoring

Water quality monitoring is a critical element in assessing the current status of water resources and the historical trends. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and document the status of the waterbody in terms of achieving total maximum daily loads and water quality standards (WQS).

3.6.1 Monitoring Plan to Track TMDL Effectiveness

Continuing monitoring plays an important role in determining what practices result in load reductions and the attainment of WQS. Continued monitoring will:

- Assess the future beneficial use status;
- Determine if water quality is improving, getting worse, or staying the same;
- Evaluate the effectiveness of implemented best management practices.

Table 3-2 is an example monitoring plan.

Table 3-2. Example Monitoring Plan for Individual Segments.

Parameter(s)	Sampling Interval	Sampling Duration	Purpose
E. coli and flow	Weekly snapshot	Throughout recreation season (ongoing)	Evaluate ambient conditions
Microbial source tracking (MST)	Snapshot	At least two sampling events within recreation season.	Determine the source(s) of *E. coli*
E. coli (continuous sampling)	15-60 minutes	Throughout precipitation events and periods of high winds to determine more completely the transport mechanism of *E. coli* from the beach environment to the swimming zone.	Evaluate the importance of environmental conditions

Adjustment of parameters, and sampling intervals should be based on newly discovered or suspected pollutant sources, BMP placement/installation, and other dynamic factors.

3.7. Public Participation

There are 34 lakes in the State of Iowa listed on the 2016 impaired waters list that are impaired for bacteria. The initial submittal of this WQIP will include beaches at 3 lakes; Hickory Grove, Clear Lake (McIntosh Woods State Park and Clear Lake State Park), and Nine Eagles. Subsequent beach bacteria TMDLs will be submitted as amendments to this WQIP.

Appendix E will contain information regarding public meetings, written comments, and other public comments. As additional beach bacteria TMDLs are prepared and submitted Appendix E will be amended to reflect the new submittals.

4. Hickory Grove Lake TMDL

4.1. Description and History of Hickory Grove Lake

Hickory Grove Lake, IA 03-SSK-950, is located in Nevada Township Story County, Iowa approximately 2.5 miles southwest of the City of Colo. The lake was constructed in the 1950's and is located on land owned and operated by the Story County Conservation Board. The lake and land surrounding it provide fishing, camping, hiking and other outdoor recreational activities for the public.

The lake has a watershed area of approximately 4,037 acres, a maximum depth of 34.6 feet, a shore length of 5.2 miles, and an approximate volume of 1,216 acre feet. Table 4-1 is a summary of the lake and watershed properties. Figure 4-1 is an aerial photograph with the boundaries of the watershed.

Table 4-1. Hickory Grove Watershed and Lake Information.

Waterbody Name	Hickory Grove Lake
Waterbody ID	IA 03-SSK-950
12 Digit Hydrologic Unit Code (HUC)	070801050604
HUC-12 Name	East Indian Creek
Location	Section 19, T83N, R21W & Section 24, T83N, R22W, Story County Iowa
Water Quality Standard Designated Uses	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life HH Human Health
Tributaries	Unnamed Stream
Receiving Waterbody	Unnamed Stream to East Indian Creek
Watershed Area	4,037 acres
Lake Surface Area	100 acres
Maximum Depth	34.6 feet
Volume	1,216 ac-feet
Length of Shoreline	27,200 feet
Watershed/Lake Area Ratio	40:1

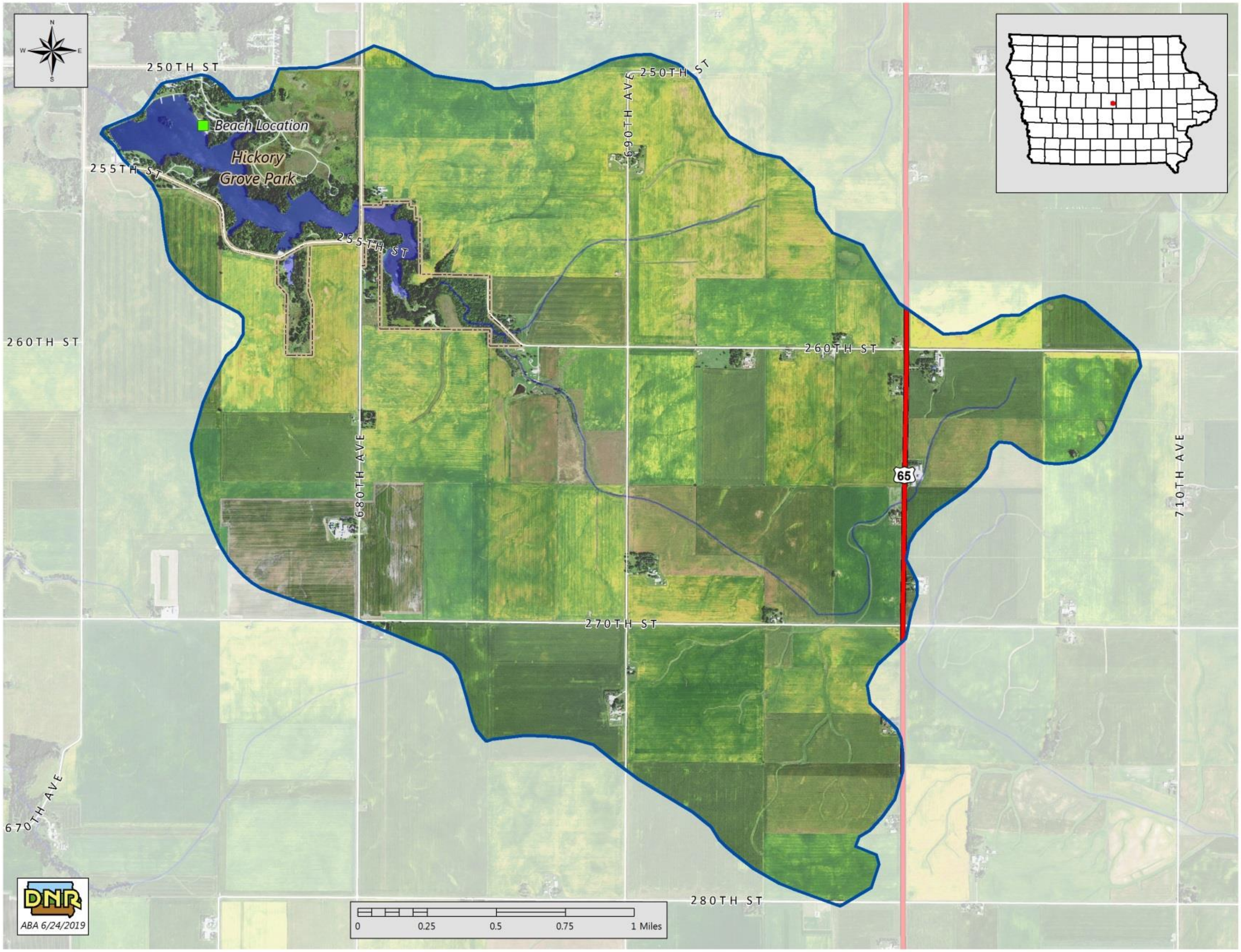


Figure 4-1. Hickory Grove Lake Watershed.

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using the 2014 USDA Cropland Data Layer (USDA, National Agricultural Statistics Service). The two predominate land uses are two subtypes of row crops (corn and soybeans), with row crops making up approximately 82.6% (56.3% corn, 26.3 soybean) (Table 4-2). The seven land uses shown in Table 4-2 were aggregated from the ten land uses in the cropland data layer as shown in the description column. Figure 4-2 shows the distribution of the various land uses throughout the Hickory Grove watershed in a pie-chart.

Table 4-2. Hickory Grove Watershed Land Uses.

Land Use	Description	Area (AC)	Percent of total
Water/Wetland	Water and Wetlands	113	2.8%
Forested	Bottomland, Coniferous, Deciduous	105	2.6%
Grassland	Ungrazed, Grazed, & CRP-	226	5.6%
Alfalfa/Hay	Perennial Hay Crop-	6	0.1%
Row crop	Corn, Soybeans, & other	3,333	82.6%
Roads	Roads Lightly Developed Urban	228	5.6%
Urban	Intensively Developed Urban	26	0.7%
Total		**4,037**	**100%**

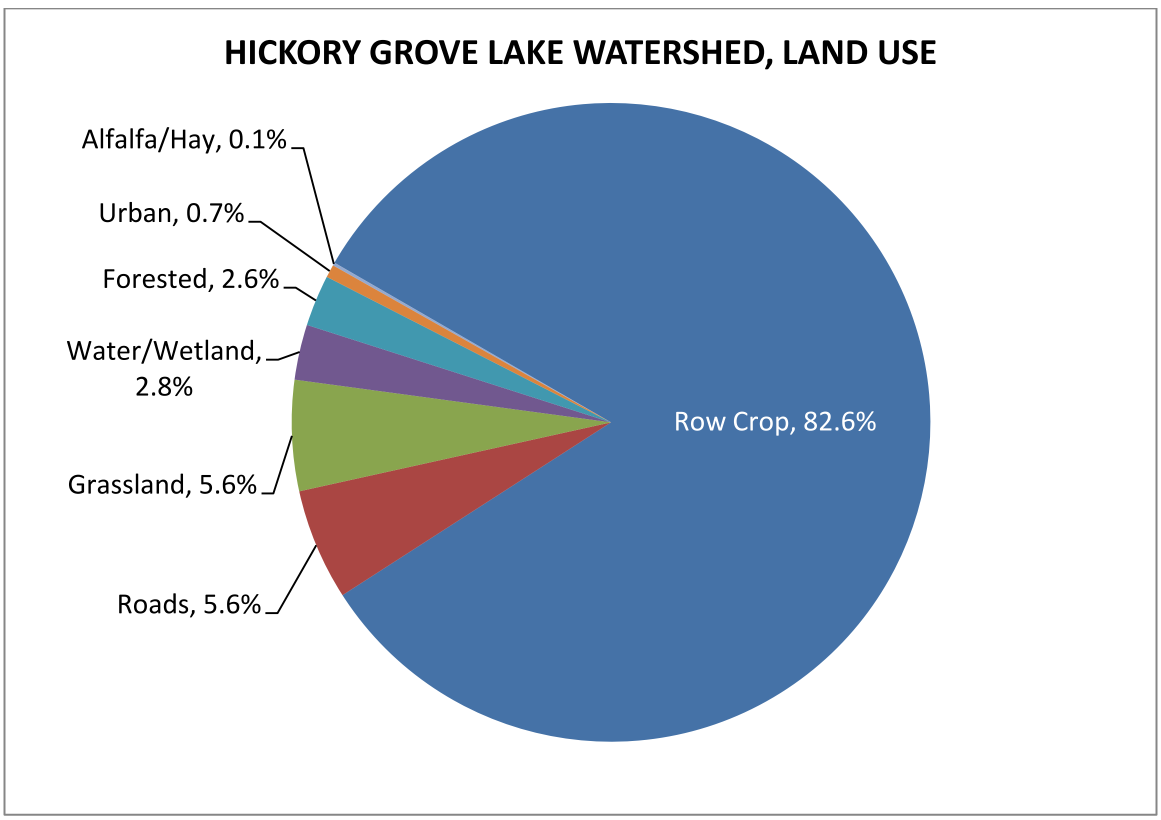


Figure 4-2. Land Use Composition of the Hickory Grove Lake Watershed.

Hydrology, Soils, Climate, Topography

From data obtained from the NRCS, there are 8 main soils types in this watershed. No soil type makes up a majority in the area. The top three soil types in the watershed are the Clarion-Nicollet-Webster soil complex, which makes up 78.8% of the soil types in the watershed. Of the seven hydrologic soil types, hydrologic soil type B makes up the majority of the soils in the watershed at 55.3%. The topography for the Hickory Grove Lake watershed consists of relatively flat uplands with a few prairie pothole features typical of the Des Moines Lobe landform region that it occupies. As a result, the upland slopes tend to be less than 3 percent until much closer to the lake.

The average rainfall for Hickory Grove Lake in Story County is 36 inches with the majority falling between April and October. Lake evapotranspiration averages 31 inches per year with more occurring in dryer years on average. Figure 4-3 shows the annual rainfall and reference evapotranspiration from 2002 to 2018. Figure 4-4 shows the monthly average relationship between watershed evapotranspiration and rainfall. In some drier summer months evapotranspiration may exceed rainfall, leading to a deficit in the water budget for the watershed.

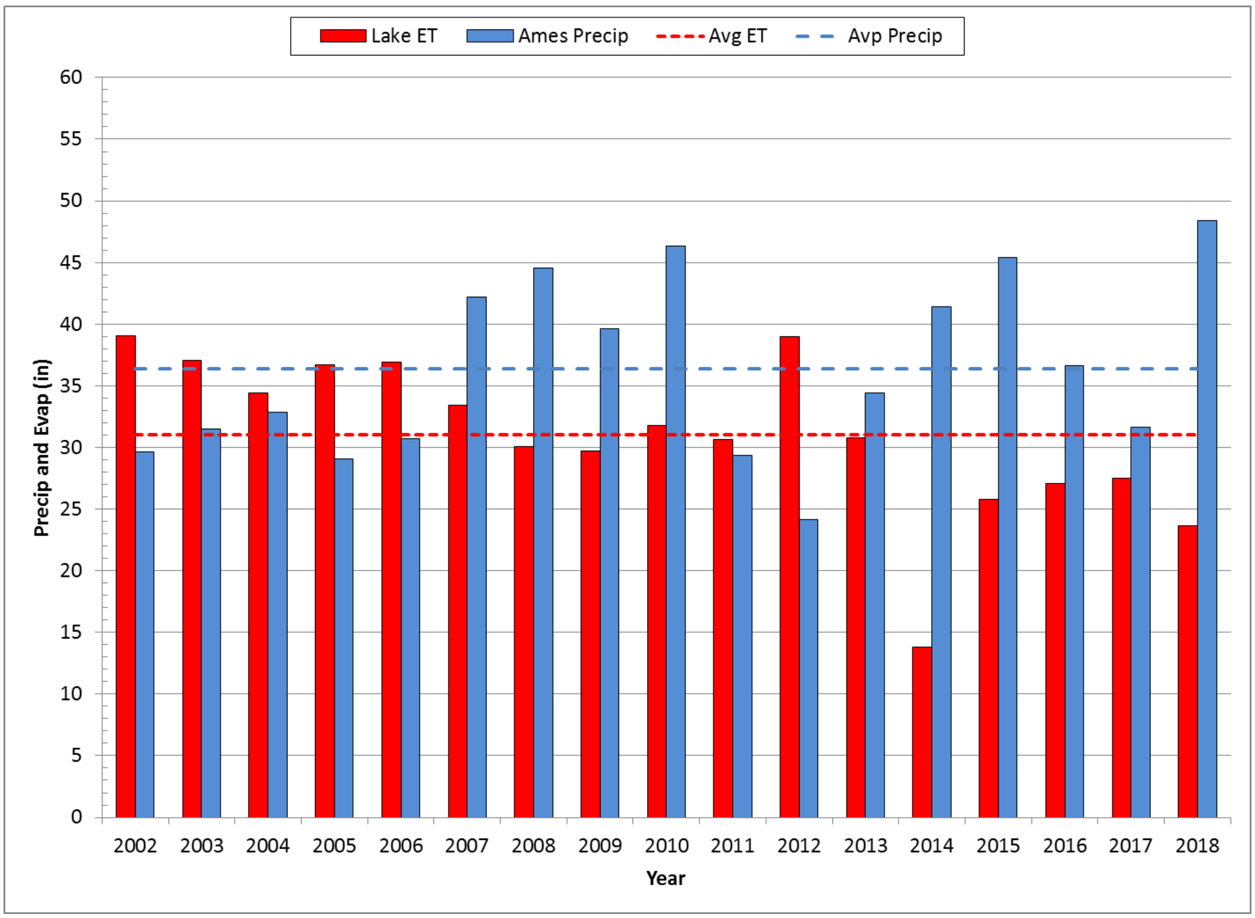


Figure 4-3. Annual Rainfall and Estimated Evapotranspiration Totals, Hickory Grove Watershed.

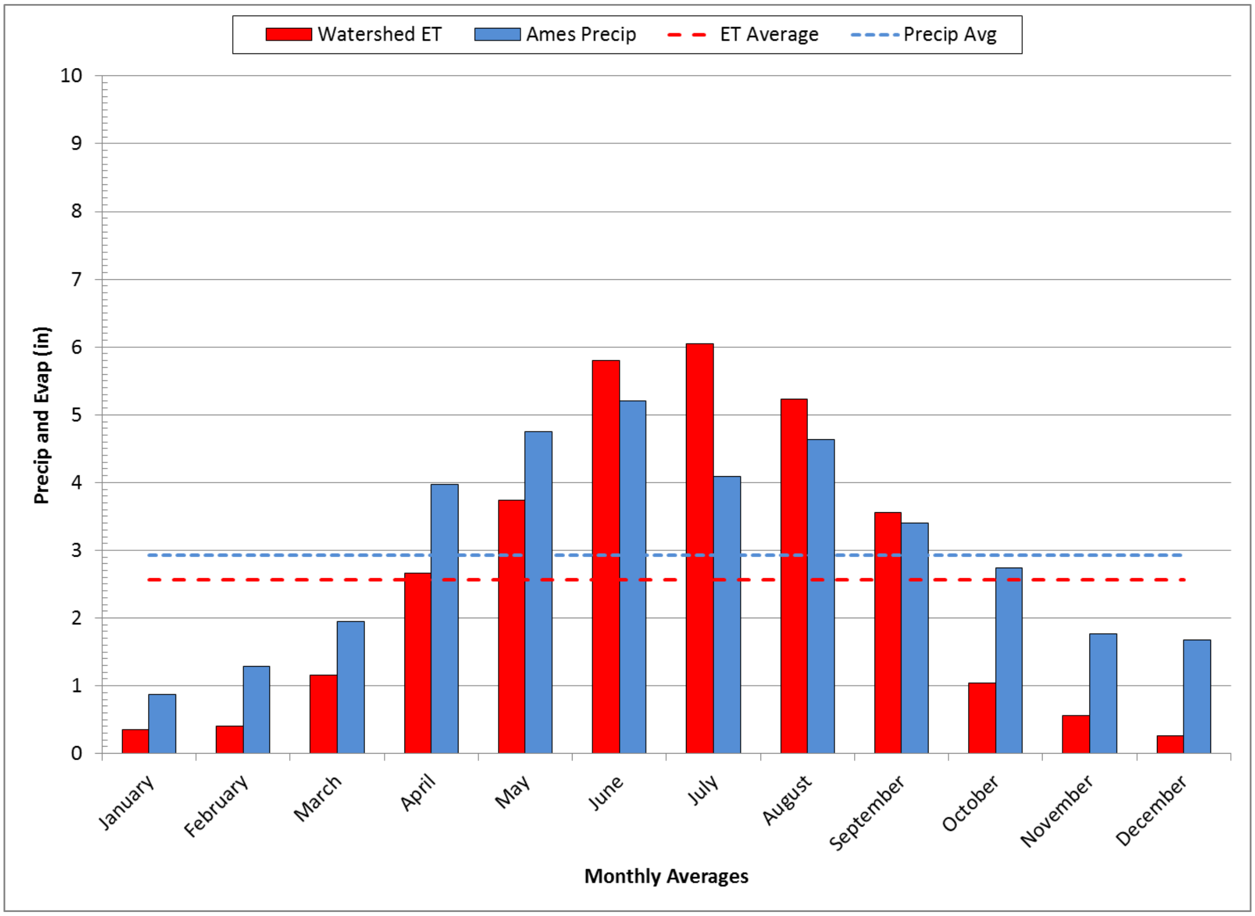


Figure 4-4. Monthly Rainfall and Estimated Evapotranspiration Totals, Hickory Grove Watershed.

4.2. TMDL for Hickory Grove Lake Beach.

The WQIP has provided general background information around the impaired lake. However, the sampling and monitoring of the lake that resulted in the impairment are located in the swimming zone of the Hickory Grove Park. In addition, the data presented in Chapter 2 demonstrate that the source of the impairment comes for the beach area and not from the general watershed area of the lake.

Consequently, the TMDL will focus on the beach shed area and the swimming zone that it drains to.

Problem Identification

Hickory Gove Lake, IA 03-SSK-950, was included on the 2008 impaired waters (303(d)) list for not fully supporting Class A1 (primary contact recreation) uses due to the presence of high levels of *E. coli*. Samples were collected during the recreational season (March 15 – November 15) between 2004 – 2018 as part of the state's ambient water quality monitoring and assessment program.

In 2015, 2016, and 2018 additional water quality samples were collected by the Iowa DNR to study and assess the relationships between the nearshore beach environment and open lake conditions. Results of this study are included in Chapter 2 of this WQIP.

Applicable Water Quality Standards
The designated uses of Hickory Grove Lake are: primary contact recreational use (Class A1); lakes and wetlands (Class B(LW)); and human health (Class HH). The designated uses are defined in the Iowa Administrative Code (567 Iowa Administrative Code, Chapter 61, (IAC)). For a more detailed description of the designated uses see Appendix B

Near Shore Beach Volume (NSBV)
The NSBV is the volume of water contained within the swimming zone of the lake. Figure 4-5 shows the swimming and beach shed areas of Hickory Grove Lake. Table 4-3 is a summary of the NSBV data.

Figure 4-5. Swimming and Beach Shed Areas, Hickory Grove Lake.

Table 4-3. Hickory Grove Swimming Zone and NSBV Data.

Near Shore Beach Volume	0.97 acre-feet
Beach Front Length	346.7 feet
Radius from Shore at midpoint of beach	62.9 feet
Depth at Radius	4.2 feet (Elevation 967.8)
Beach Shed Area	2.8 Acres

Data Sources and Monitoring Sites

Table 4-4 lists the water quality monitoring locations used to develop this WQIP. Figure 4-6 shows the monitoring locations used. In addition to these sites, samples were collected adjacent to the beach along three transects as shown in Figure 4-7. For a more detailed description of the samples collected along the transects see Chapter 2.

Table 4-4. WQ Data Monitoring Sites at Hickory Grove Lake.

Site Name	Site ID	Longitude	Latitude
HIC T-4(1)	14000188	93° 21' 49"	41° 59' 23"
HICKGRV1(1)	14000168	93° 21' 40"	41° 59' 30"
HICKGRV2(1)	14000170	93° 21' 26"	41° 59' 15"
HICKGRV3(1)	14000171	93° 21' 09"	41° 59' 08"
HICKGRV4(1)	14000172	93° 20' 53"	41° 59' 09"
Hickory Grove Park Beach(2)	21850001	93° 21' 31"	41° 59' 26"

(1) 2015 Iowa DNR Study sampling site.
(2) Ambient water quality sampling site.

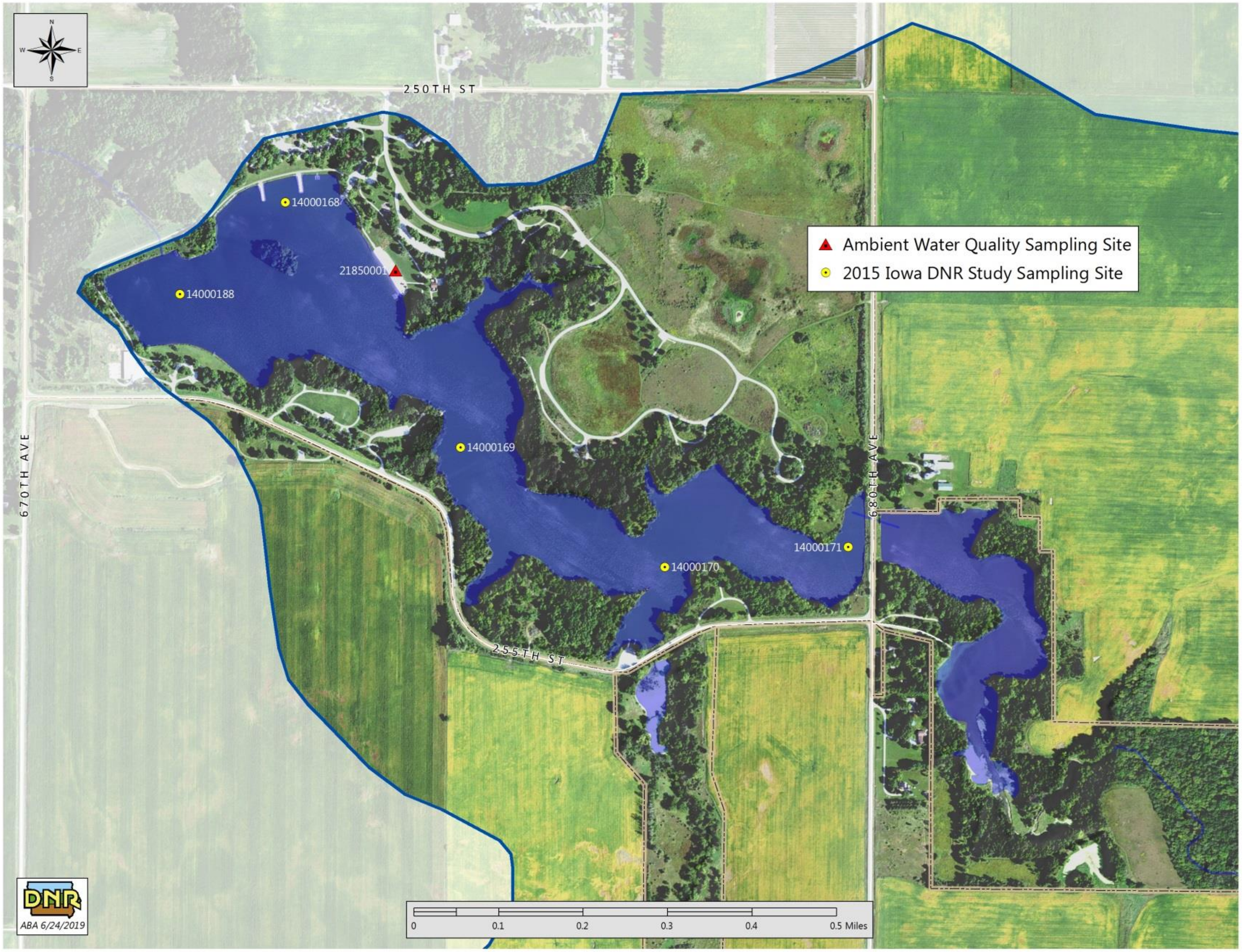


Figure 4-6. Sampling Locations, Hickory Grove Lake.

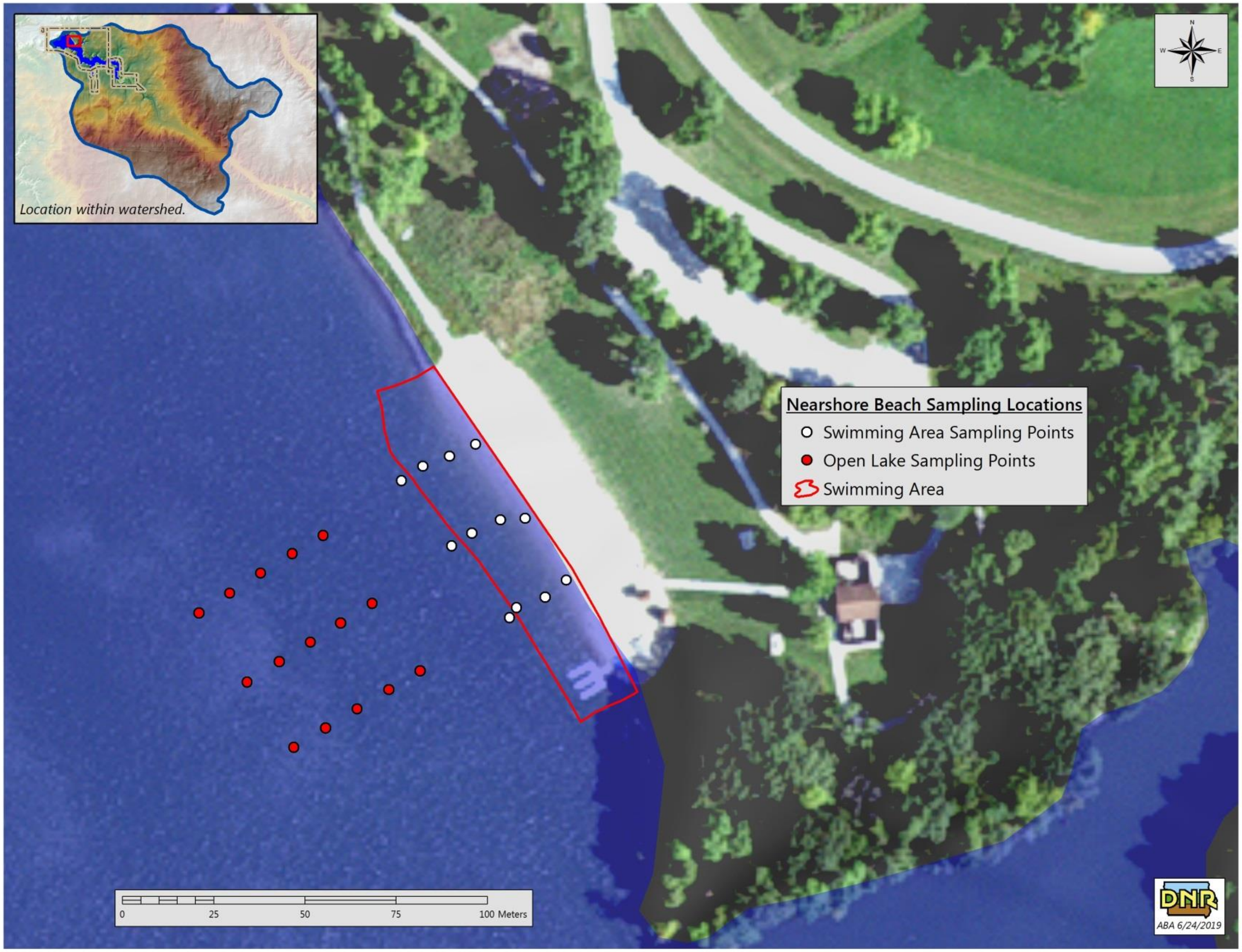


Figure 4-7. Nearshore Beach Sampling Locations, Hickory Grove Lake.

Interpretation of Data
Analysis of the data shows consistently high *E. coli* levels that exceed the criterion set for in Iowa's WQS for primary contact recreation. Significant reductions in *E. coli* loading will be required to comply with the standards and fully support the designated recreational use in the impaired waterbody.

Using data collected from 2004 – 2018, two box plots were developed. Figure 4-8 is a box plot of samples categorized by season (spring, summer, and fall) and a plot of the full data. The box has lines at the lower quartile, median, and upper quartile values. Whiskers extend from the top and bottom to the existing loading and the minimum load. The existing load for each box is the 90^{th} percentile of observed *E. coli* concentrations. In some cases, the minimum load and the lower quartile value are coincidental to each other. There is also a horizontal line representing the SSM concentration of 235 orgs/ 100 mL.

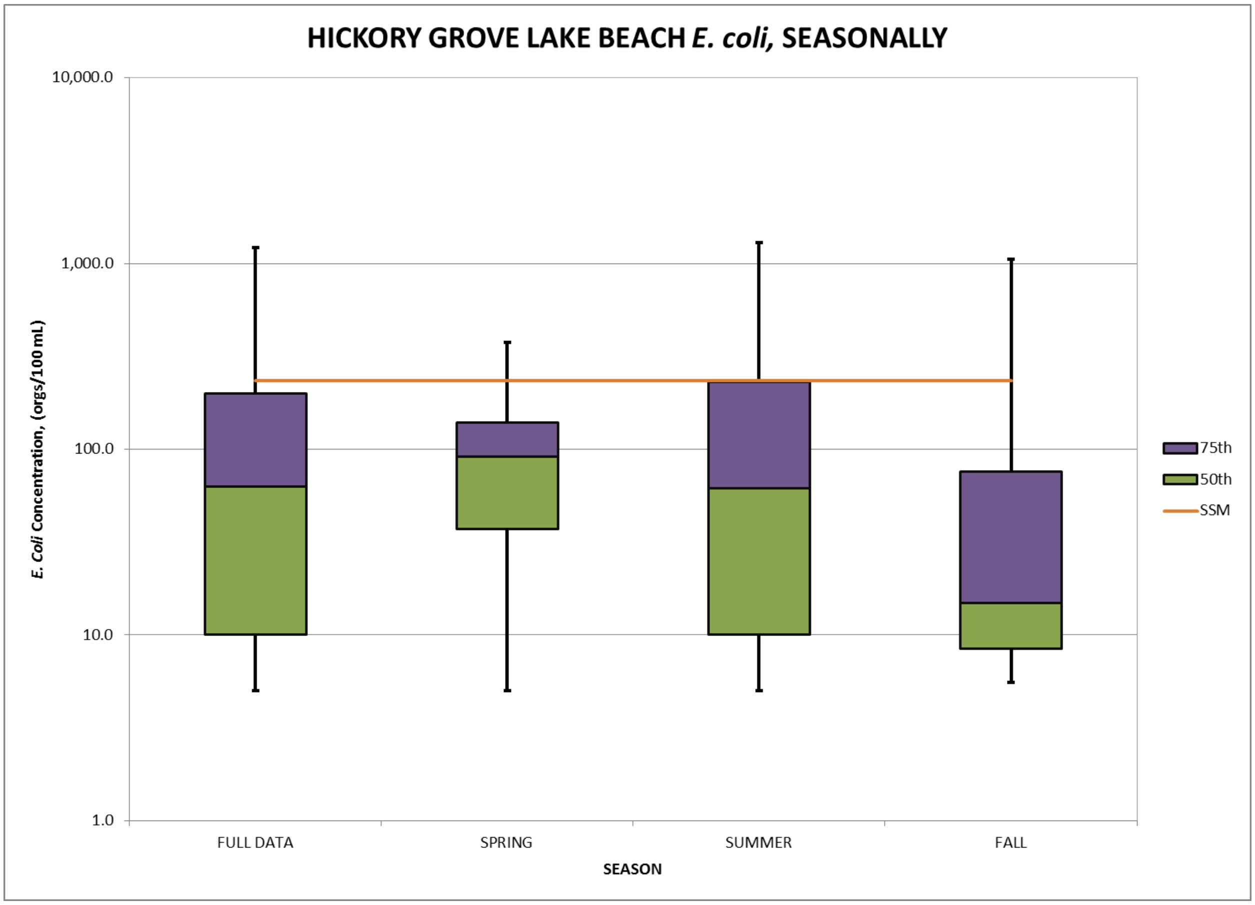


Figure 4-8. Seasonal Box Plot, Hickory Grove Lake.

From Figure 4-8 it can be seen that there are elevated levels of bacteria throughout the entire recreational season at the Hickory Grove beach.

In the second box plot graph, Figure 4-9, data is categorized by month. This box plot has the same format as previously described. From this figure is can be seen that the levels of bacteria are at its highest in late summer and early fall. The general trend is for bacteria levels to increase from spring into summer and decrease in the late fall with the peak month being September.

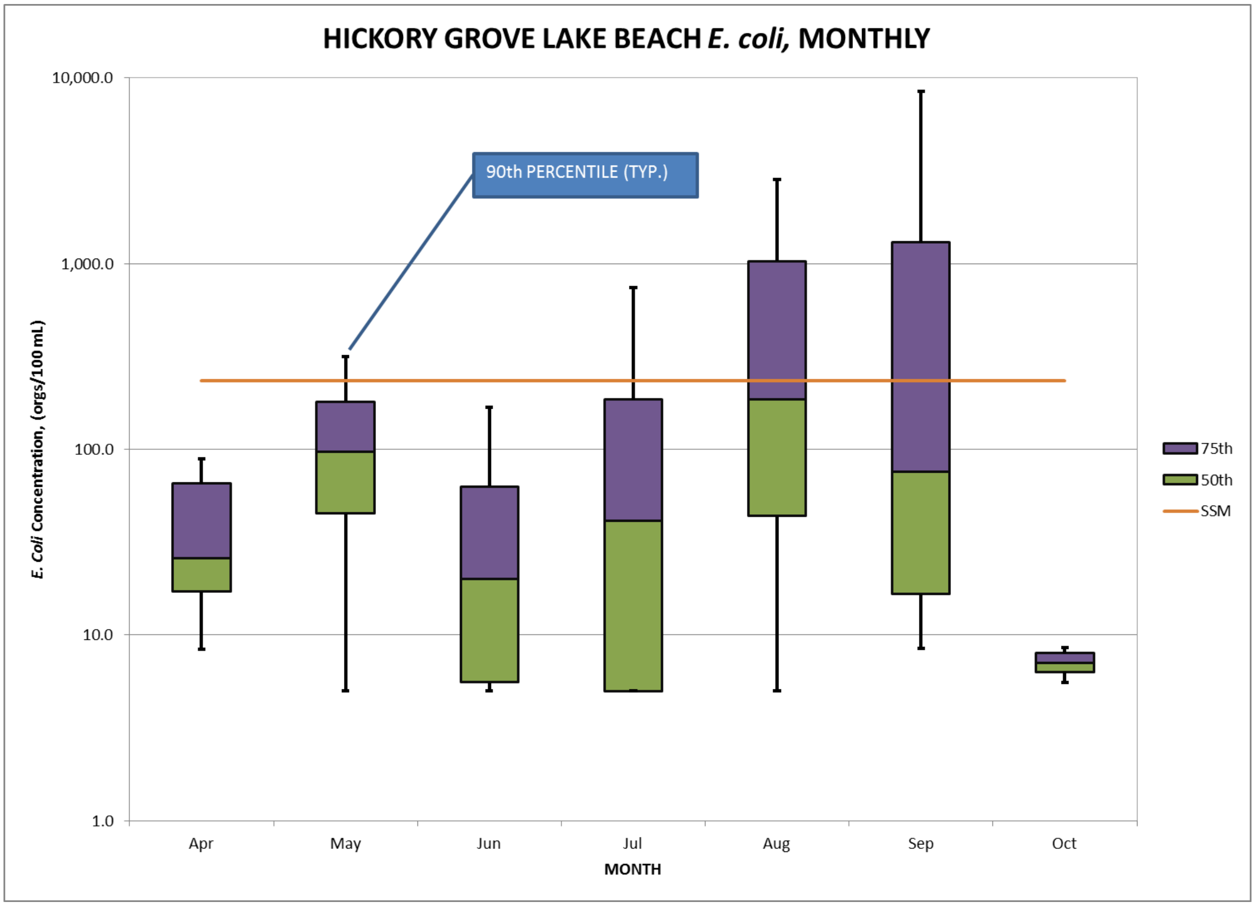


Figure 4-9. Monthly Box Plot, Hickory Grove Lake.

4.2.1. TMDL Target

General Description of Pollutant

Fecal material from warm-blooded animals contains many microorganisms. Some of these microorganisms can cause illness or disease if ingested by humans. The term pathogen refers to a disease-causing microorganism, and can include bacteria, viruses, and other microscopic organisms. Humans can become ill if they come into contact with and/or ingest water that contains pathogens.

Selection of Environmental Conditions

The critical period for the impairment occurs in the recreational season of March 15 to November 15. The critical volume is the NSBV, which is adjacent to the beach area.

Waterbody Pollutant Loading Capacity

Attainment of the WQS to fully support primary contact recreation requires that the GM for *E. coli* concentrations be no greater than 126 orgs/ 100 mL and the (SSM) be not greater than 235 orgs/ 100 mL (Iowa Administrative Code 567, Chapter 61, Water Quality Standards for Class A1 uses). The methods used to develop the *E. coli* TMDL for the Hickory Grove Lake are based on the assumption that compliance with the SSM will coincide with attainment of the GM target. Therefore, the loading capacity of the TMDL is the maximum number of *E. coli* organisms that can be in the NSBV while meeting the SSM criterion of 235 orgs/ 100 mL.

Decision Criteria for WQS Attainment
The seasonal duration curve was constructed using daily sampling data. The SSM criterion was used to quantify the loading capacity of the NSBV, in terms of load (orgs/ 100 mL). Points above the red SSM line in Figure 4-10 represent violations of the WQS, whereas points below the line comply with WQS.

WQS will be attained in the NSBV when less than 10% of samples exceed the SSM criterion of 235 orgs/ 100 mL during the recreational season of March 15 – November 15.

4.2.2. Pollution Source Assessment

Departure from Load Capacity
The seasonal load curve and observed loads for the seasonal load conditions are plotted in Figure 4-10. This methodology enables calculation of a TMDL target for each season. However, the highest percent reduction of the three seasons will be used as the target reduction for all impaired seasons. It is assumed if the highest percent reduction rate is used and achieved that WQS will be attained for GM and SSM criterion for all seasons.

Allowance for Increases in Pollutant Loads
Based on current land use and size of the beach shed area it is unlikely that any new sources will be developed within the beach shed area.

4.2.3. Pollutant Allocations

Wasteload Allocations (WLA)
There are no point sources in the beach shed of Hickory Grove Lake. Therefore, the WLA portion of this TMDL is zero.

Load Allocation (LA)
Nonpoint sources result from livestock, pets, wildlife, and humans that live, work, and play in and around the beach. Specific examples of potential nonpoint sources of bacteria include animals directly depositing into a waterbody, manure applied to row crops, manure runoff from grazed land, non-permitted onsite wastewater systems, and natural sources such as wildlife.

Based on the results of the 2-year study presented in Chapter 2 of this WQIP the source of the impairment is from the near shore beach environment. Source of *E. coli* is from water fowl loafing on the beach and regeneration of *E. coli* in the sand environment.

Margin of Safety
An explicit margin of safety (MOS) of 10 percent is applied to the calculation of loading capacities in this TMDL. Additionally, targeting the GM in each flow condition, rather than only the overall GM, provides an implicit MOS by requiring WQS compliance across flow conditions.

Seasonal Load Curve
Figure 4-10 shows a seasonal load curve for the NSBV at Hickory Grove Lake. Table 4-5 and Table 4-6 are the existing load estimates and the TMDL summary, respectively.

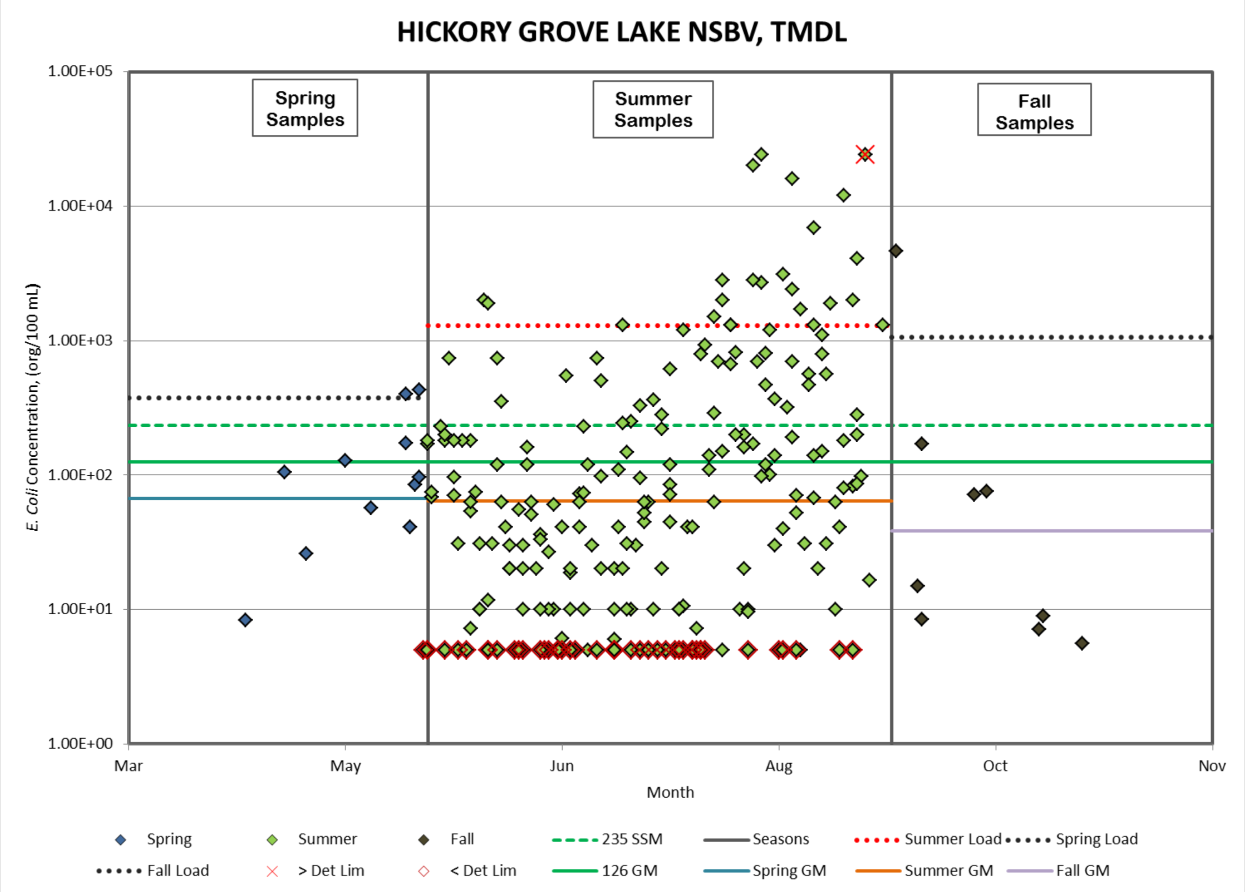


Figure 4-10. Seasonal Load Curve, Hickory Grove Lake, Near Shore Beach Volume.

Table 4-5. Existing Load Estimates for the NSBV at Hickory Grove Lake.

Load Summary	**Seasonal Loads (org/ 100 mL)**		
	Spring(1)	**Summer**	**Fall(1)**
Observed Load(2)	377.2	1,300.0	1,056.0
Departure	142.2	1,065.0	821.0
(% Reduction)	(37.7)	(81.9)	(77.7)

(1) Not assessed as impaired. Less than 10% of samples exceeded the SSM criterion of 235 orgs/ 100 mL.
(2) Observed load is the 90th percentile of water quality samples..

Table 4-6 is a summary of the TMDL for the NSBV at Hickory Grove Lake. Because it is assumed that the NSVB is constant from year to year the TMDL calculations do not change from season to season.

Table 4-6. TMDL Summary for the NSBV at Hickory Grove Lake.

	TMDL
TMDL (org/ 100 mL)	235.0
WLA (org/ 100 mL)	0.0
LA (org/ 100 mL)	211.5
MOS (org/ 100 mL)	23.5

4.2.4. TMDL Summary

This TMDL is based on meeting the water quality criteria for primary contact and children's recreation in Hickory Grove Lake. Although the WQS are based on *E. coli* concentration, the TMDL is expressed as a total mass. In light of the November 2006 EPA memorandum. The following equation represents the total maximum daily load (TMDL) and its components:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

Where: TMDL = total maximum daily load
LC = loading capacity
ΣWLA = sum of wasteload allocations (point sources)
ΣLA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

Once the loading capacity, waste load allocations, load allocations, and margin of safety are determined for the lake, the general equation above can be expressed for *E. coli* as the allowable daily load. Using the values in Table 4-6 and a NSBV of 0.97 acre-feet the TMDL for Hickory Grove NSBV as a mass loading is presented in Table 4-7.

Table 4-7. Summary of Hickory Grove Lake.

	TMDL
TMDL (orgs/day)	2.81E+09
WLA (orgs/day)	0.00E+00
LA (orgs/day)	2.53E+09
MOS (orgs/day)	2.81E+08

Appendix 4.A – Water Quality Data

Table 4.A-1. Water Quality Sampling Data, Beach Monitoring, Hickory Grove Lake, SITE ID 21850001.

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/2/2004	54	7/30/2006	5	6/22/2009(3)	5
6/14/2004	< 10(2)	8/7/2006	700	6/29/2009(3)	5
6/21/2004	60	8/14/2006	320	7/6/2009(3)	41
6/28/2004	10	8/21/2006	20	7/13/2009(3)	63
7/6/2004	110	5/22/2007	< 10(2)	7/20/2009(3)	10
7/12/2004	45	5/29/2007	70	7/27/2009(3)	110
7/19/2004	< 10(2)	6/4/2007	10	8/3/2009(3)	10
7/27/2004	140	6/11/2007	30	8/10/2009(3)	1,200
8/4/2004	200	6/18/2007	36	8/17/2009(3)	5
8/10/2004	100	6/25/2007	10	8/24/2009(3)	1,900
8/16/2004	70	7/2/2007	20	8/31/2009(3)	98
8/30/2004	280	7/9/2007	10	9/8/2009(3)	4,600
5/23/2005	< 10(2)	7/16/2007	20	9/14/2009(3)	170
6/6/2005	< 10(2)	7/23/2007	< 10(2)	6/14/2010	20
6/13/2005	55	7/30/2007	150	6/21/2010	10
6/20/2005	< 10(2)	8/6/2007	170	6/28/2010	74
6/27/2005	73	8/13/2007	40	7/5/2010	< 10(2)
7/5/2005	20	8/20/2007	140	7/12/2010	52
7/11/2005	< 10(2)	8/27/2007	80	7/18/2010	610
7/18/2005	45	5/27/2008	180	7/26/2010	930
7/25/2005	< 10(2)	6/2/2008	180	8/9/2010	120
8/1/2005	1300	6/8/2008	120	8/16/2010	< 10(2)
8/8/2005	2700	6/16/2008	63	8/23/2010	31
8/15/2005	190	6/23/2008	< 10(2)	8/30/2010	200
8/22/2005	150	6/30/2008	30	5/23/2011	170
8/29/2005	82	7/7/2008	20	6/6/2011	1,900
5/23/2006	< 10(2)	7/14/2008	10	6/14/2011	30
5/30/2006	< 10(2)	7/21/2008	1,200	6/27/2011	63
6/5/2006	2000	7/28/2008	1,500	7/5/2011	< 10(2)
6/12/2006	< 10(2)	8/4/2008	160	7/11/2011	95
6/19/2006	< 10(2)	8/11/2008	30	7/18/2011	85
6/26/2006	< 10(2)	8/18/2008	31	7/25/2011	790
7/5/2006	6	8/25/2008	10	8/1/2011	670
7/10/2006	30	5/27/2009(3)	200	8/8/2011	98
7/17/2006	< 10(2)	6/8/2009(3)	740	8/15/2011	700

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
7/24/2006	< 10(2)	6/15/2009(3)	120	8/22/2011	790
8/29/2011	< 10(2)	7/14/2014	360	5/10/2016(4)	57
5/21/2012	430	7/21/2014	< 10(2)	5/18/2016	400
5/29/2012	97	7/28/2014	63	5/24/2016(4)	69
6/4/2012	10	8/5/2014	< 10(2)	5/24/2016	75
6/11/2012	20	8/11/2014	370	5/31/2016	180
6/18/2012	< 10(2)	8/19/2014	470	6/6/2016(4)	12
6/25/2012	< 10(2)	8/26/2014	41	6/7/2016	31
7/2/2012	98	4/20/2015(4)	105	6/14/2016	10
7/9/2012	250	5/4/2015(4)	129	6/20/2016(4)	27
7/16/2012	220	5/18/2015(4)	172	6/22/2016	< 10(2)
7/23/2012	< 10(2)	5/19/2015	41	6/28/2016	230
7/30/2012	2000	5/26/2015	230	7/5/2016	10
8/6/2012	2800	6/1/2015	< 10(2)	7/7/2016(4)	243
8/9/2012	470	6/2/2015(4)	7	7/12/2016	63
8/13/2012	3,100	6/8/2015	< 10(2)	7/18/2016(4)	72
8/20/2012	1,300	6/9/2015(4)	350	7/20/2016	10
8/27/2012	12,000	6/15/2015	160	7/26/2016	< 10(2)
9/5/2012	1,300	6/22/2015	< 10(2)	8/2/2016(4)	819
5/20/2013	85	6/23/2015(4)	6	8/2/2016	200
5/28/2013	740	6/29/2015	120	8/9/2016	800
6/3/2013	75	7/7/2015	1,300	8/15/2016(4)	2,408
6/10/2013	41	7/8/2015(4)	149	8/16/2016	52
6/17/2013	20	7/13/2015	< 10(2)	8/23/2016	560
6/24/2013	550	7/20/2015	< 10(2)	8/30/2016(4)	4,089
7/1/2013	< 10(2)	7/21/2015(4)	11	8/30/2016	86
7/8/2013	10	7/28/2015	290	9/13/2016(4)	15
7/15/2013	< 10(2)	8/4/2015	20	9/26/2016(4)	71
7/22/2013	41	8/5/2015(4)	10	10/11/2016(4)	7
7/29/2013	700	8/11/2015	140	5/23/2017	180
8/5/2013	10	8/17/2015	1,700	5/30/2017	31
8/12/2013	< 10(2)	8/20/2015(4)	68	6/6/2017	< 10(2)
8/19/2013	560	8/25/2015	63	6/13/2017	< 10(2)
8/26/2013	< 10(2)	9/1/2015	24,000	6/20/2017	10
5/27/2014	< 10(2)	9/2/2015(4)	17	6/27/2017	41
6/2/2014	63	9/14/2015(4)	8	7/5/2017	< 10(2)
6/9/2014	63	9/29/2015(4)	75	7/11/2017	330

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/16/2014	51	10/12/2015(4)	9	7/18/2017	120
6/23/2014	41	10/21/2015(4)	6	7/25/2017	< 10(2)
7/1/2014	740	4/11/2016(4)	8	8/1/2017	1,300
7/8/2014	31	4/25/2016(4)	26	8/8/2017	24,000
8/15/2017	16,000	6/25/2018	20	8/27/2018	180
8/22/2017	1,100	7/2/2018	500		
8/29/2017	2,000	7/9/2018	< 10(2)		
5/21/2018	97	7/16/2018	280		
5/29/2018	180	7/23/2018	41	Min =	5
6/4/2018	31	7/24/2018(4)	7	1st Quartile =	10
6/11/2018	20	7/30/2018	2,800	Median =	63
6/18/2018(4)	33	8/6/2018	20,000	3rd Quartile =	200
6/18/2018	10	8/13/2018	< 10(2)	Max =	24,000
6/25/2018(4)	19	8/20/2018	6,900	Mean =	704

(1) Unless noted samples collected by the Iowa DNR as part of Ambient water quality monitoring.
(2) *E. coli* was not detectable. The minimum detection limit is 10 org/100 mL. Consequently, 5 org/100 mL was used in calculations.
(3) Samples collected by Story County.
(4) Samples collected by Iowa DNR as part of 2015 study.

5. Clear Lake TMDL

5.1. Description and History of Clear Lake

Clear Lake, IA 02-WIN-841, is located in Clear Lake Township, Cerro Gordo County, Iowa and on the west edge of the City of Clear Lake. Clear Lake is a natural glacial lake. There are three recreational beaches on Clear Lake. Two Parks, Clear Lake State Park and McIntosh Woods State Park, are owned and operated by the Iowa DNR. The third beach, City Beach, is owned and operated by the City of Clear Lake. Much of the shoreline has also been developed by private residential tracts. The City of Ventura is located along the northwest shore of the lake. The lake and land surrounding it provide fishing, camping, hiking and other outdoor recreational activities for the public.

The lake has a watershed area of approximately 13,201 acres, a maximum depth of 29.5 feet, a shore length of 15.5 miles, and an approximate volume of 36,760 acre-feet. Figure 5-1 is an aerial photograph with the boundaries of the watershed. Table 5-1 is a summary of the lake and watershed properties.

Table 5-1. Clear Lake Watershed and Lake Information.

Waterbody Name	Clear Lake
Waterbody ID	IA 02-WIN-841
12 Digit Hydrologic Unit Code (HUC)	070802030201
HUC-12 Name	Clear Creek
Beach Location	Section 20, T96N, R22W, Cerro Gordo County Iowa
Water Quality Standard Designated Uses	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life HH Human Health
Tributaries	Clear Creek
Receiving Waterbody	Clear Creek
Watershed Area	13,201 acres
Lake Surface Area	3,645 acres
Maximum Depth	29.5 feet
Volume	36,760 ac-feet
Length of Shoreline	15.5 miles
Watershed/Lake Area Ratio	3.6:1

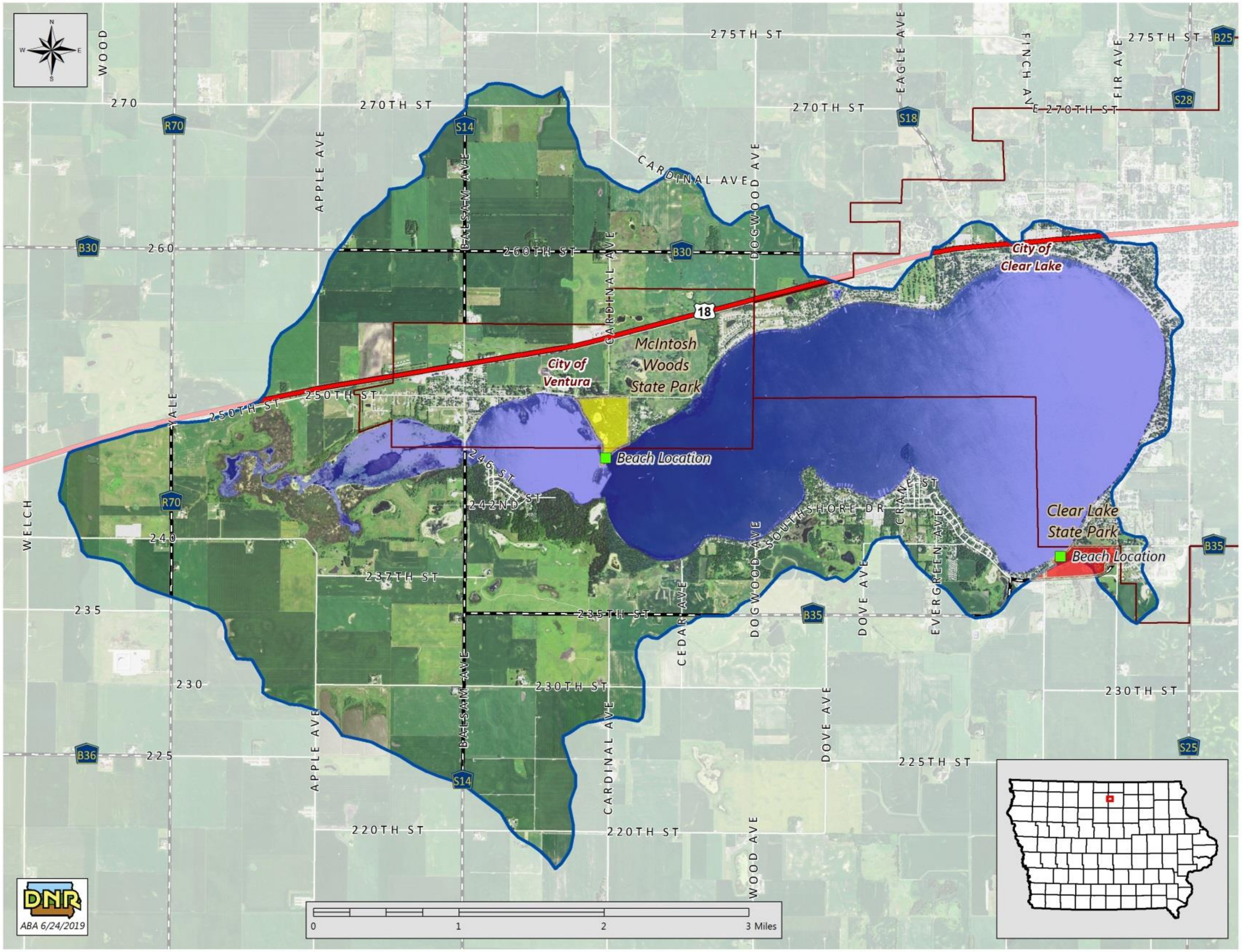


Figure 5-1. Clear Lake Watershed.

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using the 2014 USDA Cropland Data Layer (USDA, National Agricultural Statistics Service). The predominate land use are IS row crops (corn and soybeans) making up 35.5% of the land. The lake and other wetlands is the second largest land use at 33.0% (Table 5-2). The eight land uses shown in Table 5-2 were aggregated from the 14 land uses in the cropland data layer as shown in the description column. Figure 5-2 shows the distribution of the various land uses throughout the Clear Lake watershed in a pie-chart.

Table 5-2. Clear Lake Watershed Land Uses.

Land Use	Description	Area (AC)	Percent of total
Water/Wetland	Water and Wetlands	4,355	33.0%
Forested	Bottomland, Coniferous, Deciduous	467	3.5%
Grassland	Ungrazed, Grazed, & CRP-	1,846	14.0%
Alfalfa/Hay	Perennial Hay Crop-	43	0.3%
Row crop	Corn, Soybeans, & other	4,693	35.5%
Roads	Roads Lightly Developed Urban	925	7.0%
Urban	Intensively Developed Urban	864	6.5%
Barren	Barren Land	13	0.1%
Total		13,206	100.0%

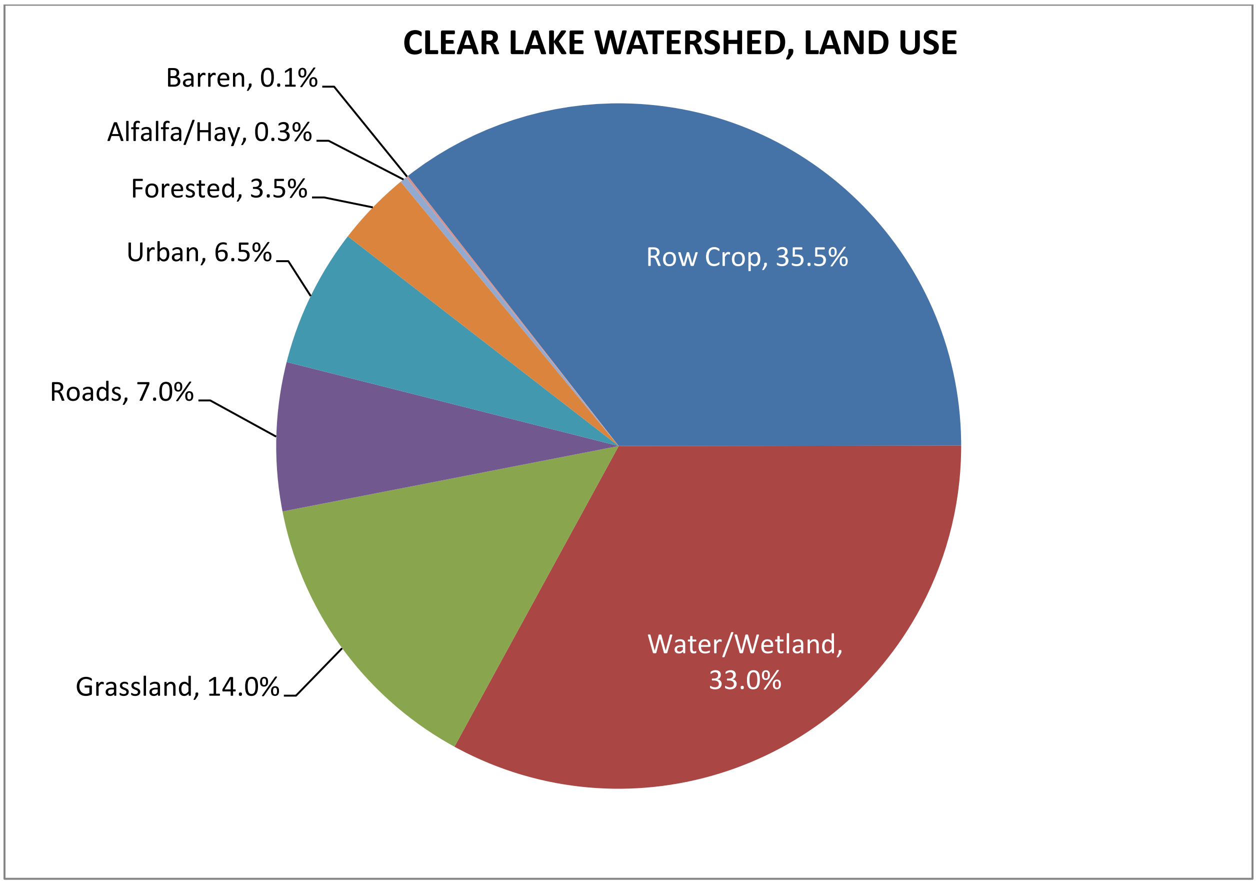


Figure 5-2. Land Use Composition of the Clear Lake Watershed.

Hydrology, Soils, Climate, Topography

From data obtained from the NRCS, there are 12 main soils types in this watershed. No soil type makes up a majority in the area. The top four soil types in the watershed are the Clarion-Nicollet-Webster soil complex along with Canisteo, which make up 39.2% of the soil types in the watershed. The topography for the Clear Lake watershed consists of relatively flat uplands with a few prairie pothole features typical of the upper Des Moines Lobe landform region that it occupies. As a result, the upland slopes tend to be less than 3 percent until much closer to the lake.

The average rainfall for Clear Lake in Cerro Gordo County is 36 inches with the majority falling between April and October. Lake evapotranspiration averages 30.6 inches per year with more occurring in dryer years on average. Figure 5-3 shows the annual rainfall and reference evapotranspiration from 2002 to 2018. Figure 5-4 shows the monthly average relationship between watershed evapotranspiration and rainfall. In some drier summer months evapotranspiration may exceed rainfall, leading to a deficit in the water budget for the watershed.

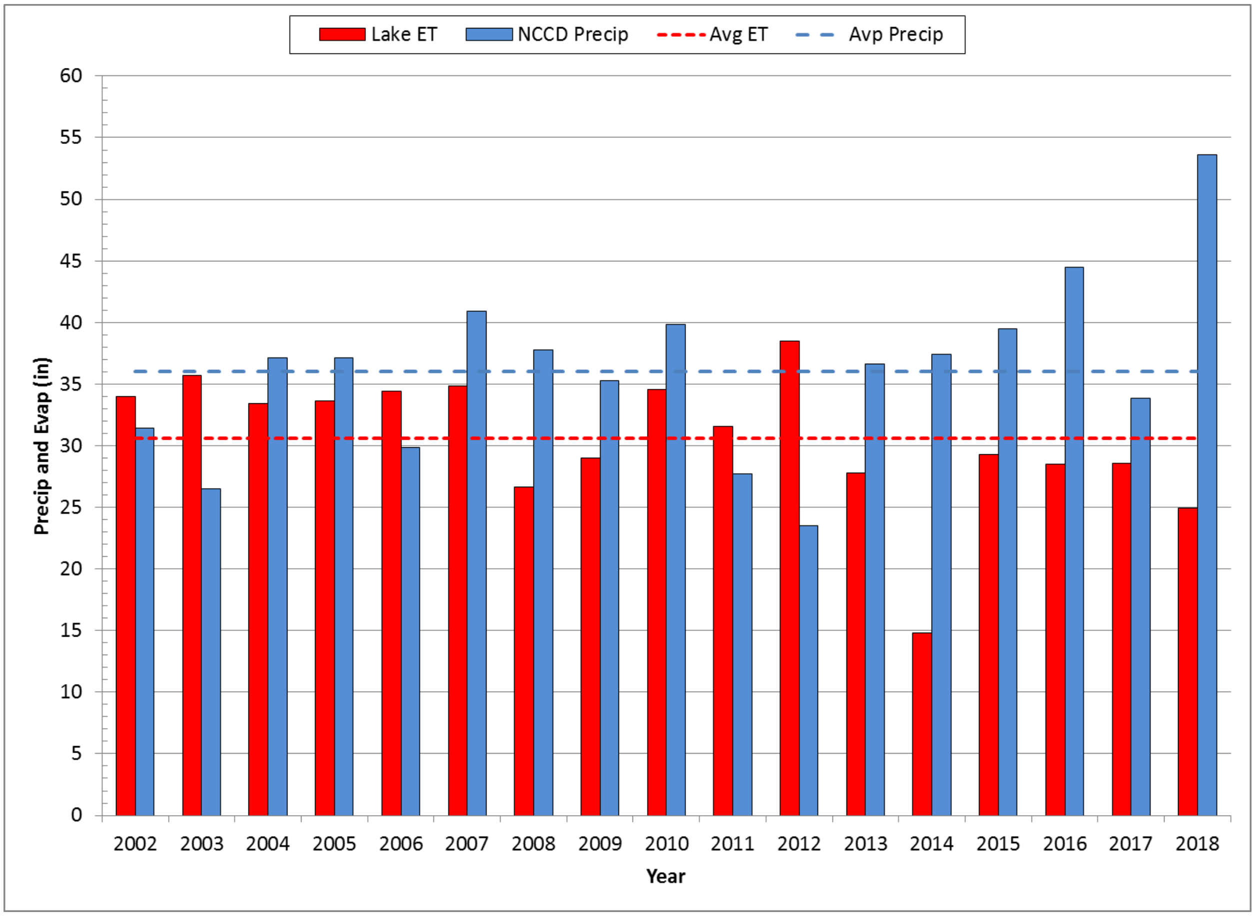


Figure 5-3. Annual Rainfall and Estimated Evapotranspiration Totals, Clear Lake Watershed.

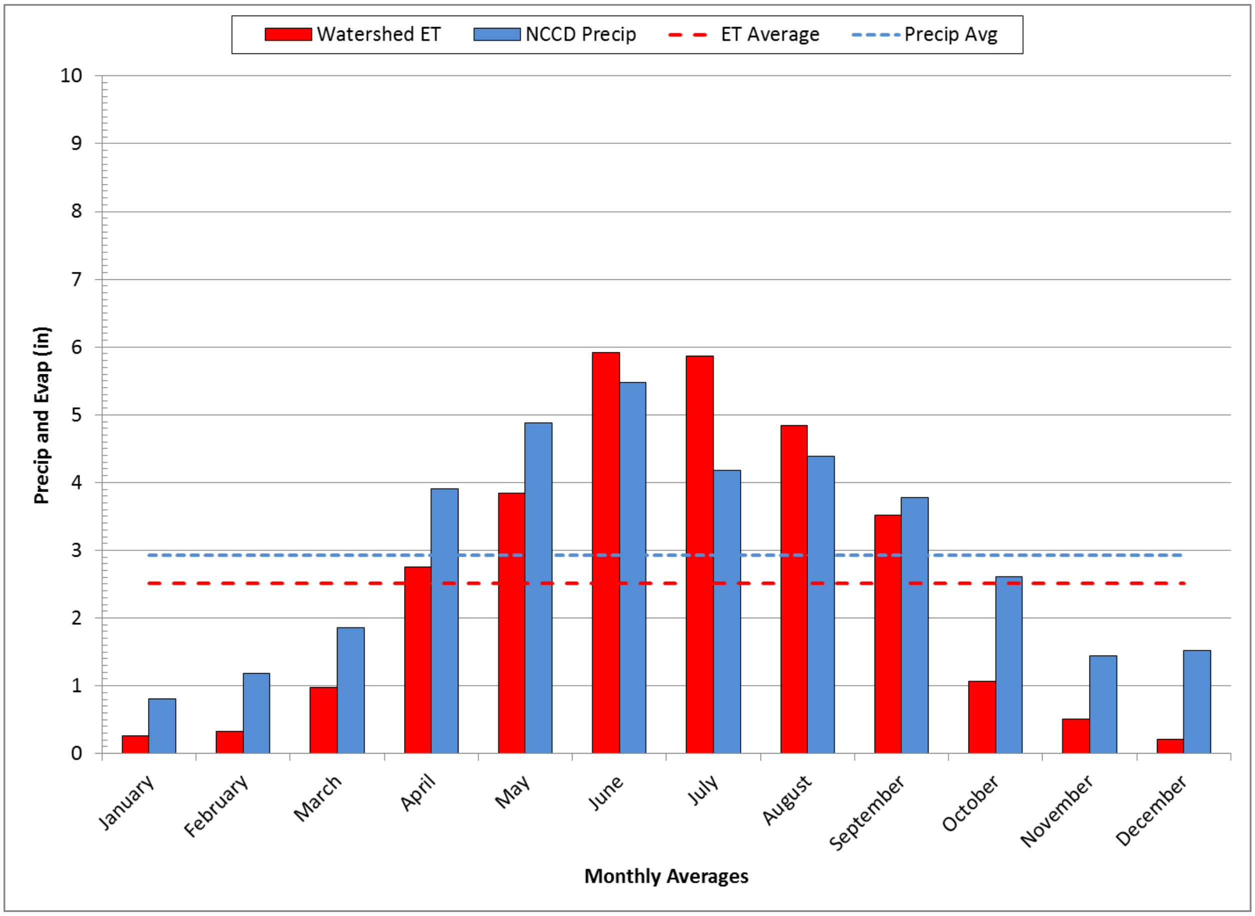


Figure 5-4. Monthly Rainfall and Estimated Evapotranspiration Totals, Clear Lake Watershed.

5.2. TMDL for Clear Lake Beaches

The WQIP has provided general background information around the impaired lake. However, the sampling and monitoring of the lake that resulted in the impairment are located in the swimming zone of the McIntosh Woods and Clear Lake State Parks. In addition, the data presented in Chapter 2 demonstrate that the source of the impairment comes for the beach area and not from the general watershed area of the lake.

Consequently, the TMDL will focus on the beach shed area and the swimming zone that it drains to.

Problem Identification

Clear Lake, IA 02-WIN-841, was included on the 2004 impaired waters (303(d)) list for not supporting Class A1 (primary contact recreation) uses due to the presence of high levels of E. coli. Samples were collected during the recreational season (March 15 – November 15) between 1999 – 2018 as part of the state's ambient water quality monitoring and assessment program.

The initial assessment placing Clear Lake on the impaired waters list came during the 2004 assessment period. The samples collected during that time period came from the near shore beach of Clear Lake State Park. Additionally, samples collected from McIntosh Woods State Park as part of the 2010 assessment period also resulted in an assessment of "not supported". Both beaches will be addressed as part of this WQIP.

In 2015, 2016, and 2018 additional water quality samples were collected at McIntosh Woods State Park by the Iowa DNR to study and assess the relationships between the nearshore beach environment and open lake conditions. Results of this study are included in Chapter 2 of this WQIP.

Applicable Water Quality Standards
The designated uses of Clear Lake are: primary contact recreational use (Class A1); lakes and wetlands (Class B(LW)); and human health (Class HH). The designated uses are defined in the Iowa Administrative Code (567 Iowa Administrative Code, Chapter 61, (IAC)). For a more detailed description of the designated uses see Appendix B.

Data Sources and Monitoring Sites
Table 5-3 lists the water quality monitoring locations used to develop this WQIP. Figure 5-5 shows the monitoring locations used. In addition, to these sites, samples were collected adjacent to the beach along three transects as part of a two year study beginning in 2015, as shown in Figure 5-6. For a more detailed discussion of the samples collected along the transects see Chapter 2.

Table 5-3. WQ Data Monitoring Sites at Clear Lake.

Site Name	ID	Longitude	Latitude
CLRLK1(1)	14000163	93° 27' 45"	43° 07' 23"
CLRLK2(1)	14000164	93° 28' 33"	43° 07' 16"
CLRLK3(1)	14000165	93° 27' 37"	43° 07' 02"
CLRLK4(1)	14000166	93° 27' 27"	43° 07' 10"
CLRLK5(1)	14000167	93° 27' 30"	43° 07' 12"
Clear Lake State Park Beach(2)	21170001	93° 23' 46"	43° 06' 40"
McIntosh Woods Beach(1) (2)	21170002	93° 27' 25"	43° 07' 16"

(1) 2015 Iowa DNR Study sampling site.
(2) Ambient water quality sampling site.

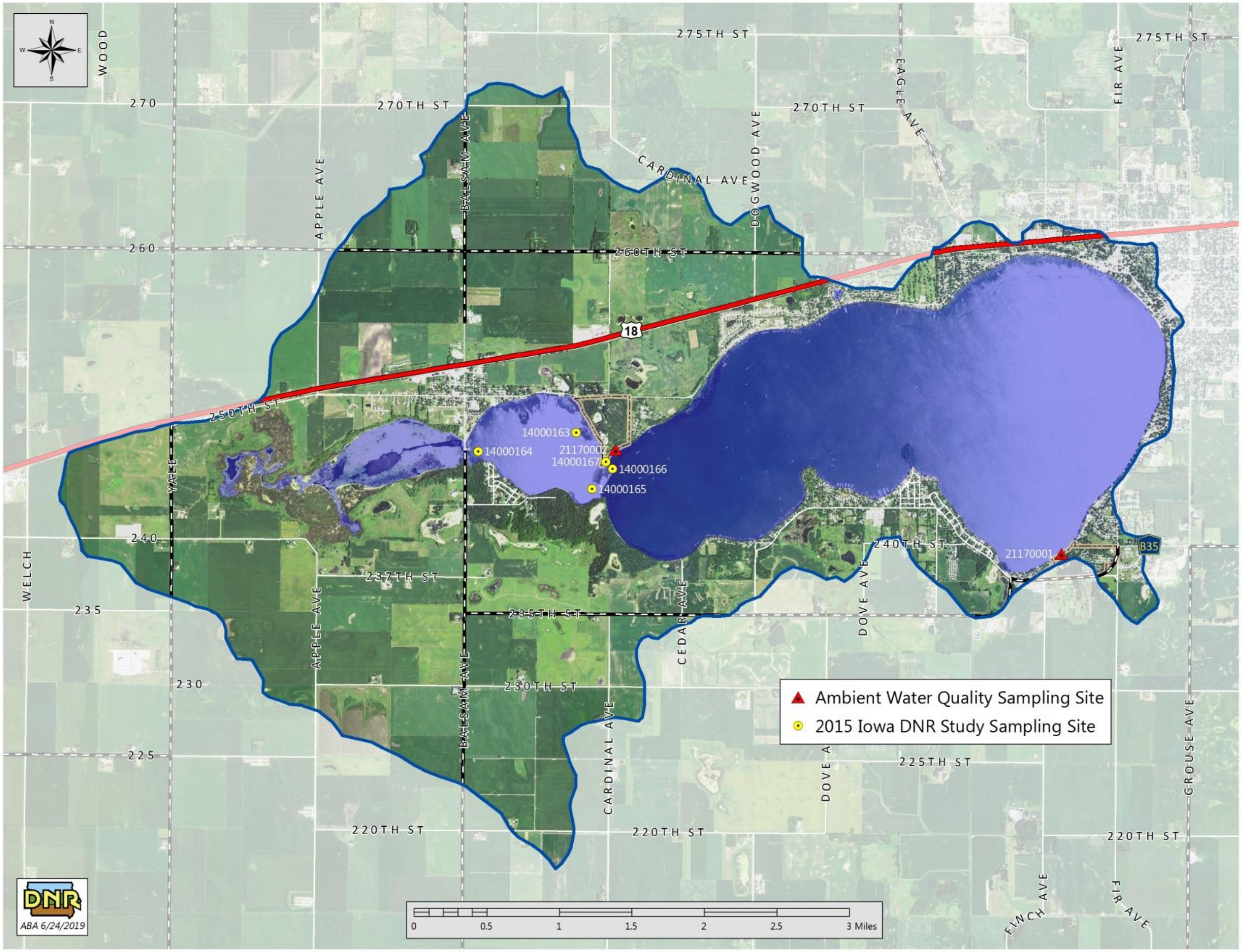


Figure 5-5. WQ Data Monitoring Sites at Clear Lake.

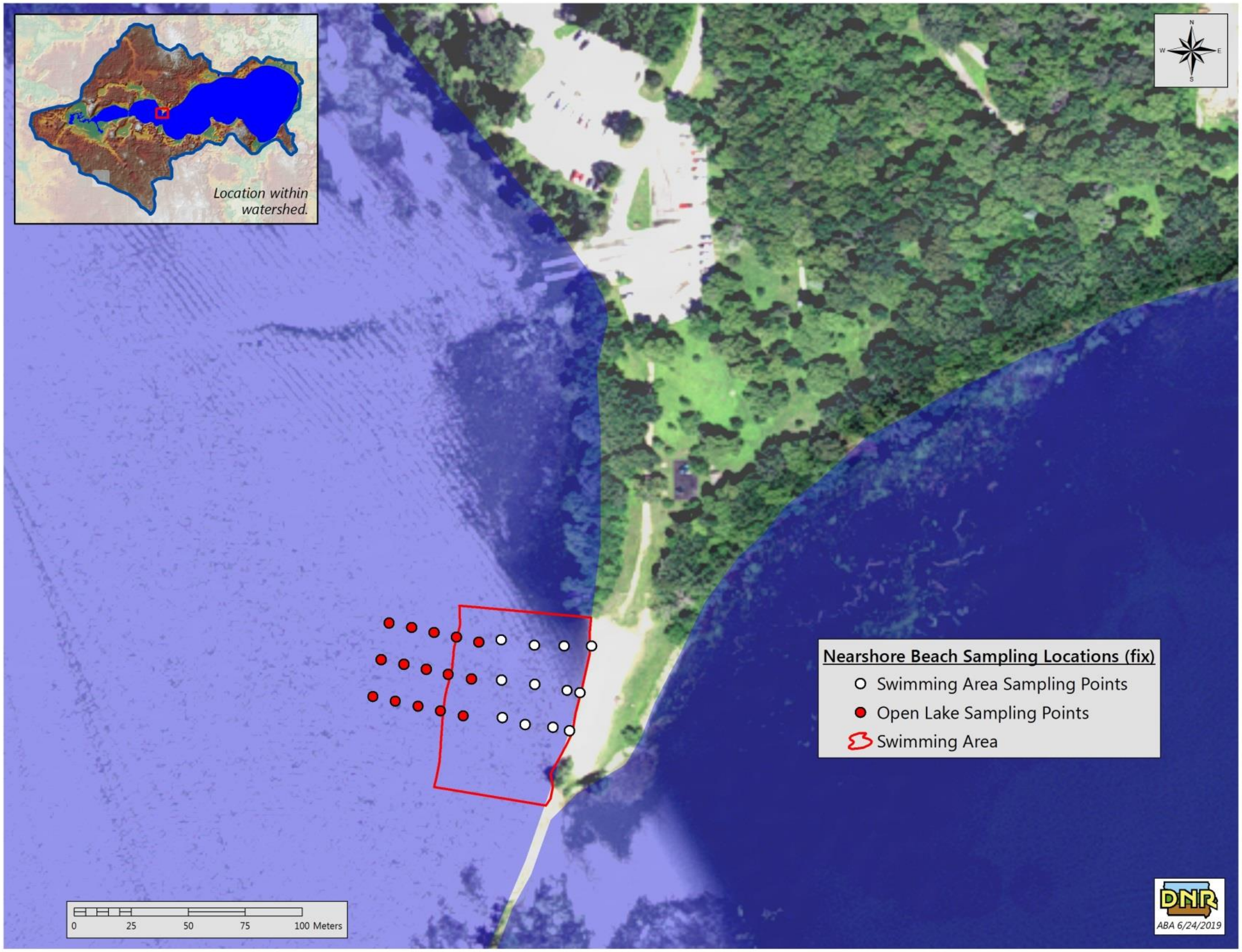


Figure 5-6. Nearshore Beach Sampling Locations, McIntosh Woods.

Near Shore Beach Volume (NSBV)

Figure 5-7 and Figure 5-8 show the swimming and beach shed areas for McIntosh Woods State Park and Clear Lake State Park, respectively. Table 5-4 and Table 5-5 are summaries of the NSBV data for McIntosh Woods State Park and Clear Lake State Park, respectively.

Table 5-4. McIntosh Woods NSBV Data.

Near Shore Beach Volume	1.0 acre-feet
Beach Front Length	284.9 feet
Radius from Shore at midpoint of beach	189.0 feet
Depth at Radius	4.04 feet (Elevation 1,223.96)
Beach Shed Area	0.7 Acres

Table 5-5. Clear Lake State Park NSBV Data.

Near Shore Beach Volume	12.3 acre-feet
Beach Front Length	825 feet
Radius from Shore at midpoint of beach	417 feet
Depth at Radius	4.1 feet (Elevation 1,223.91)
Beach Shed Area	30.0 Acres

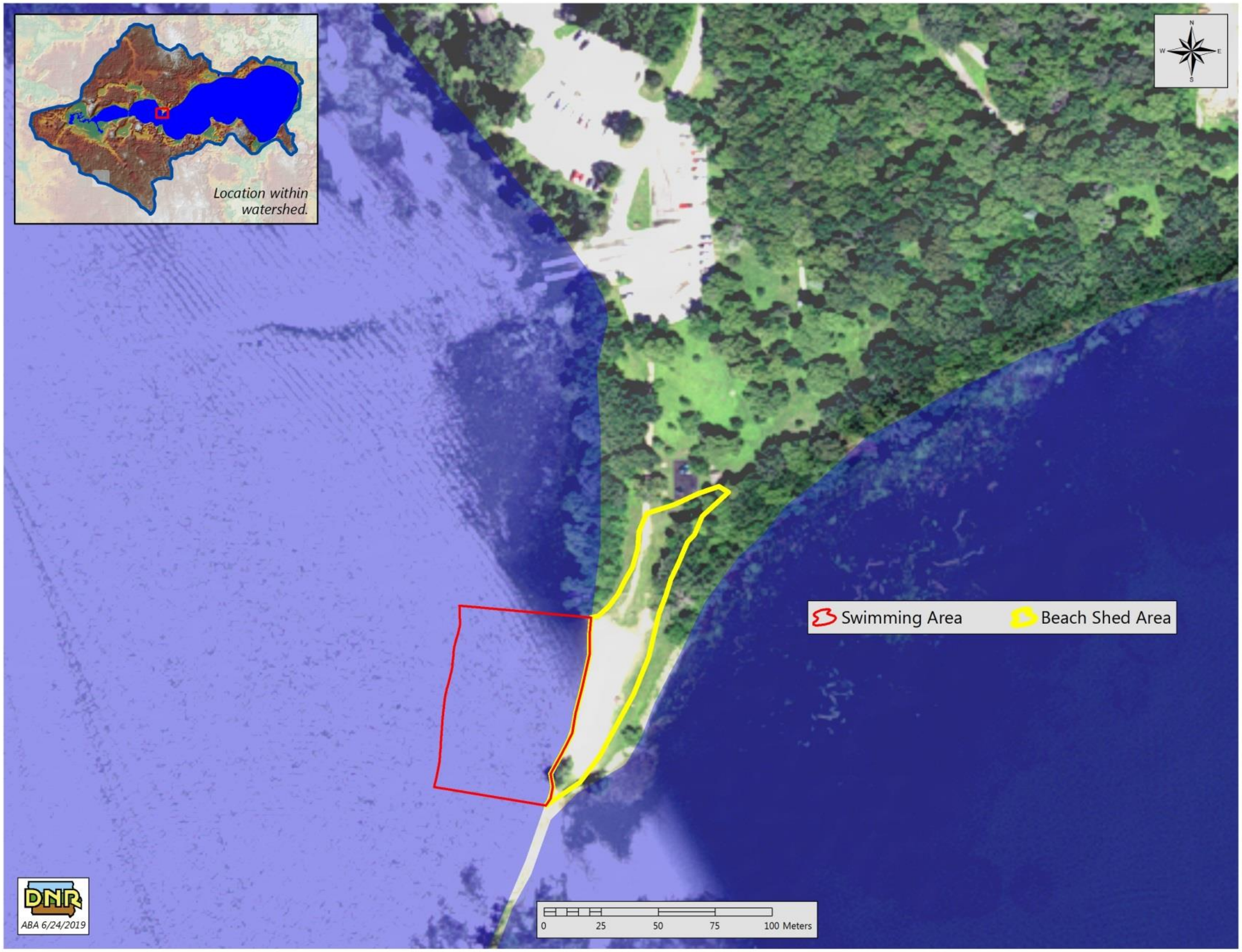


Figure 5-7. Swimming Beach Shed Areas, McIntosh Woods State Park.

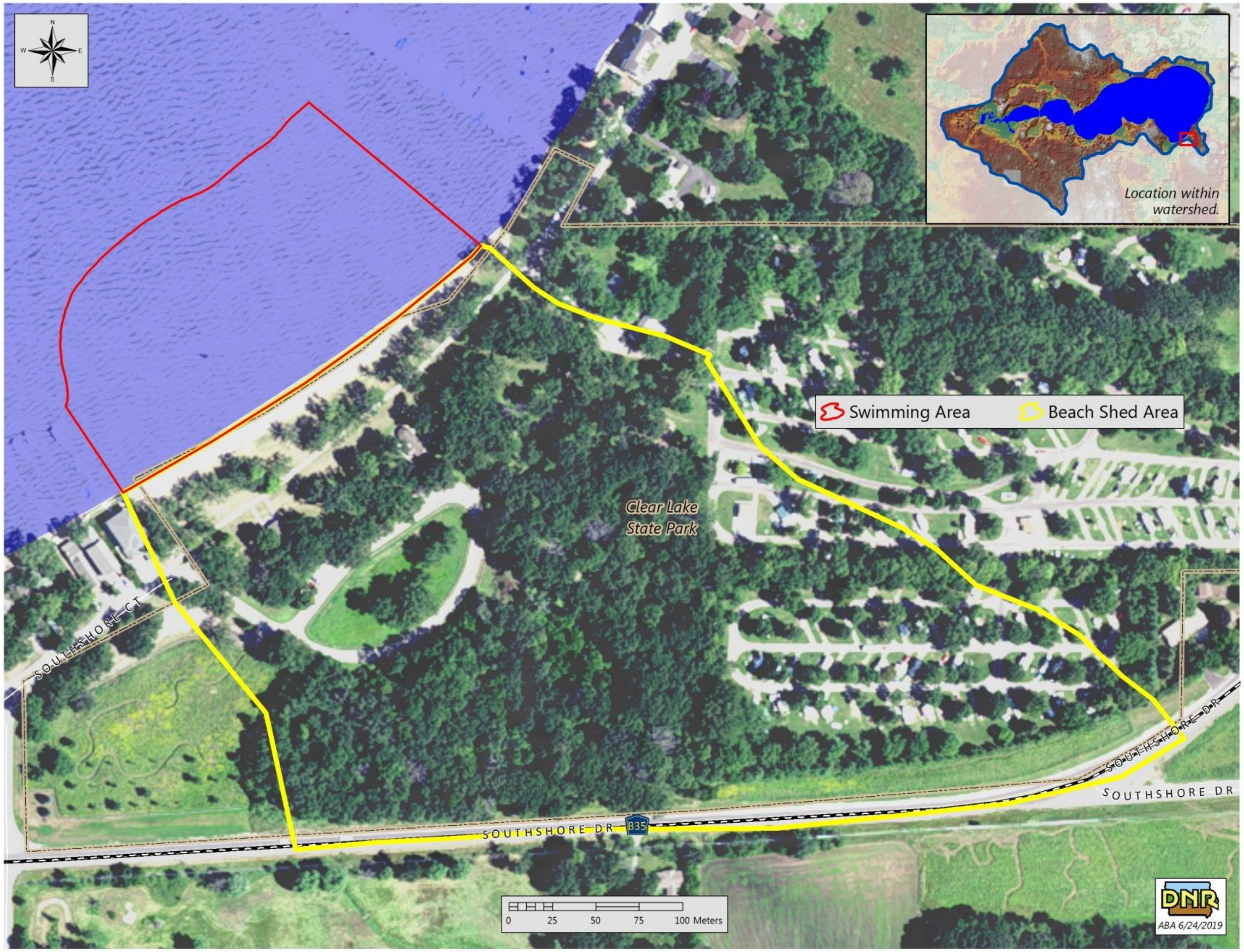


Figure 5-8. Swimming Beach Shed Areas, Clear Lake State Park.

Interpretation of Data

Analysis of the data shows consistently high *E. coli* levels that exceed the criterion set forth in Iowa's WQS for primary contact recreation. Significant reductions in *E. coli* loading will be required to comply with the standards and fully support the designated recreational use in the impaired waterbody.

Two box plots were developed for each NSBV on Clear Lake. The first box plot is categorized by season and the second box plot is categorized by month. The box plots have lines at the lower quartile, median, and upper quartile values. Whiskers extend from the top and bottom to the existing loading and the minimum load. The existing load for each box is the 90th percentile of observed *E. coli* concentrations. There is also a horizontal line representing the SSM concentration of 235 orgs/ 100 mL. Figure 5-9 and Figure 5-10 are the respective box plots for the McIntosh Woods NSBV and Figures 5-11 and 5-12 are the respective box plots for the Clear Lake NSBV.

Data used in the McIntosh Woods NBSV was collected from 2004 – 2018. Data used in the Clear lake NSBV was collected from 1999 – 2018.

Figure 5-9. Seasonal Box Plot, McIntosh Woods State Park.

From Figure 5-9 it can be seen that there are higher levels of bacteria during the summer months at the McIntosh Woods State Park beach.

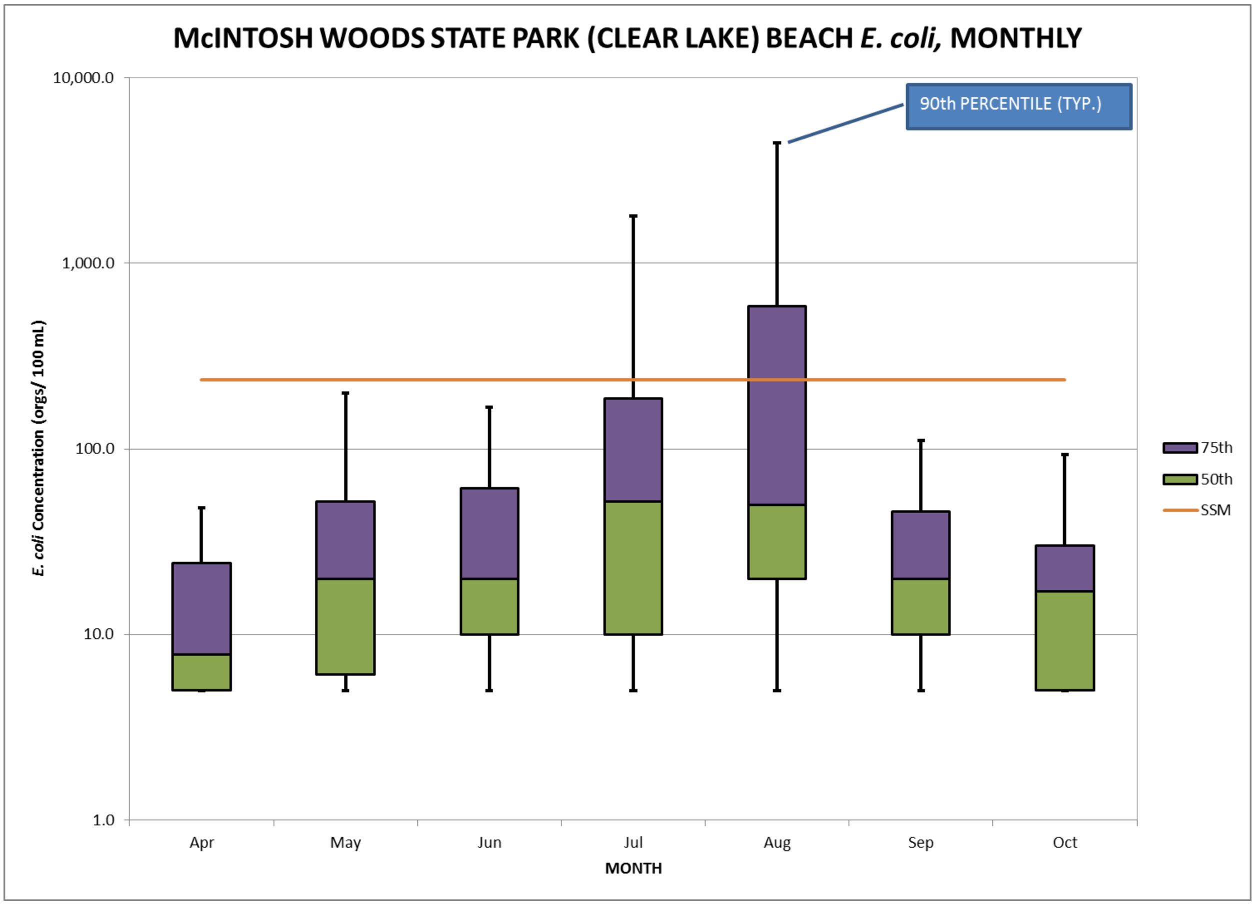


Figure 5-10. Monthly Box Plot, McIntosh Woods State Park.

From Figure 5-10 it can be seen that the level of bacteria increases during the mid to late months of summer and decrease into the fall. The general trend is for bacteria levels to increase from spring into summer and decrease in the fall with the peak month being August.

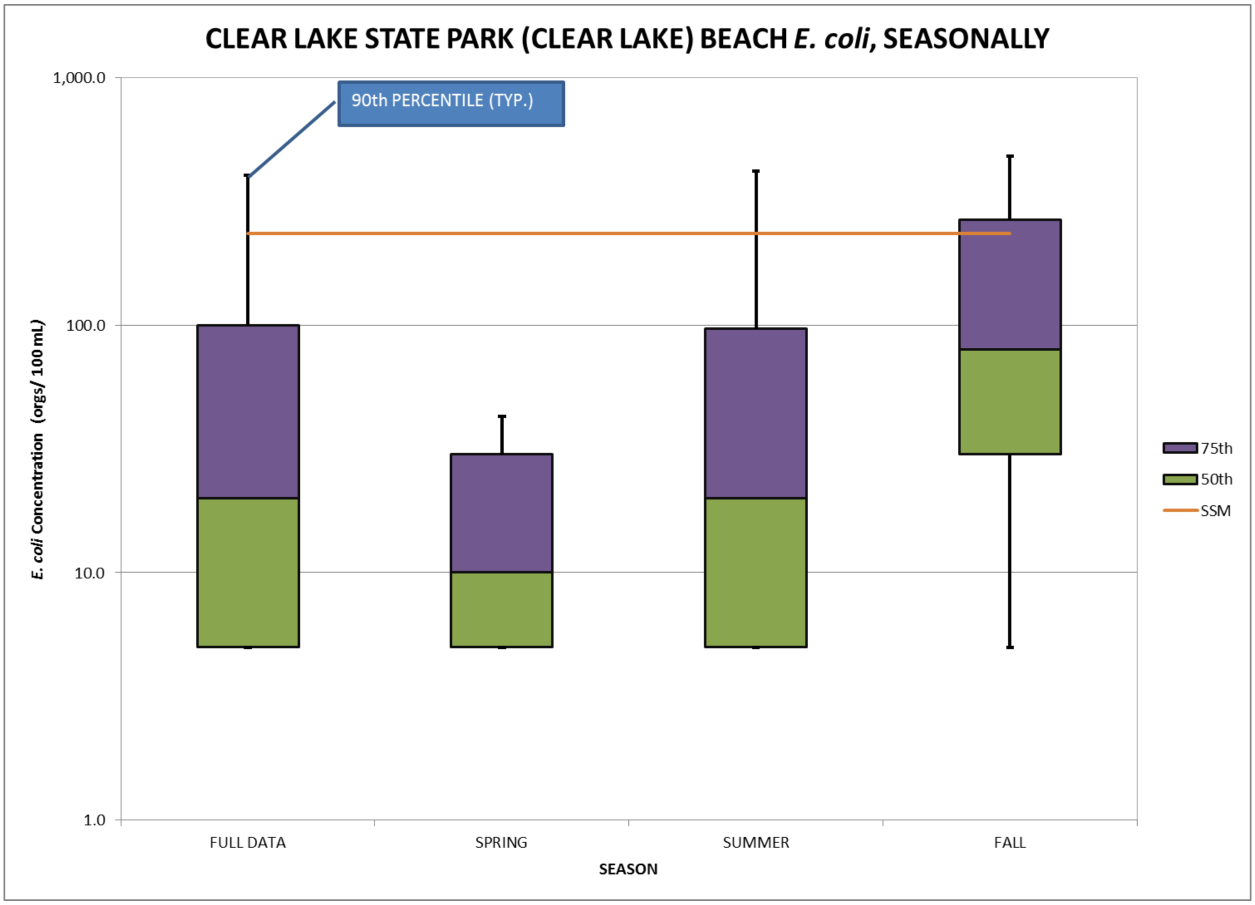


Figure 5-11. Seasonal Box Plot, Clear Lake State Park.

From Figure 5-11 it can be seen that summer and fall are the critical seasons for bacteria at the Clear Lake State Park beach.

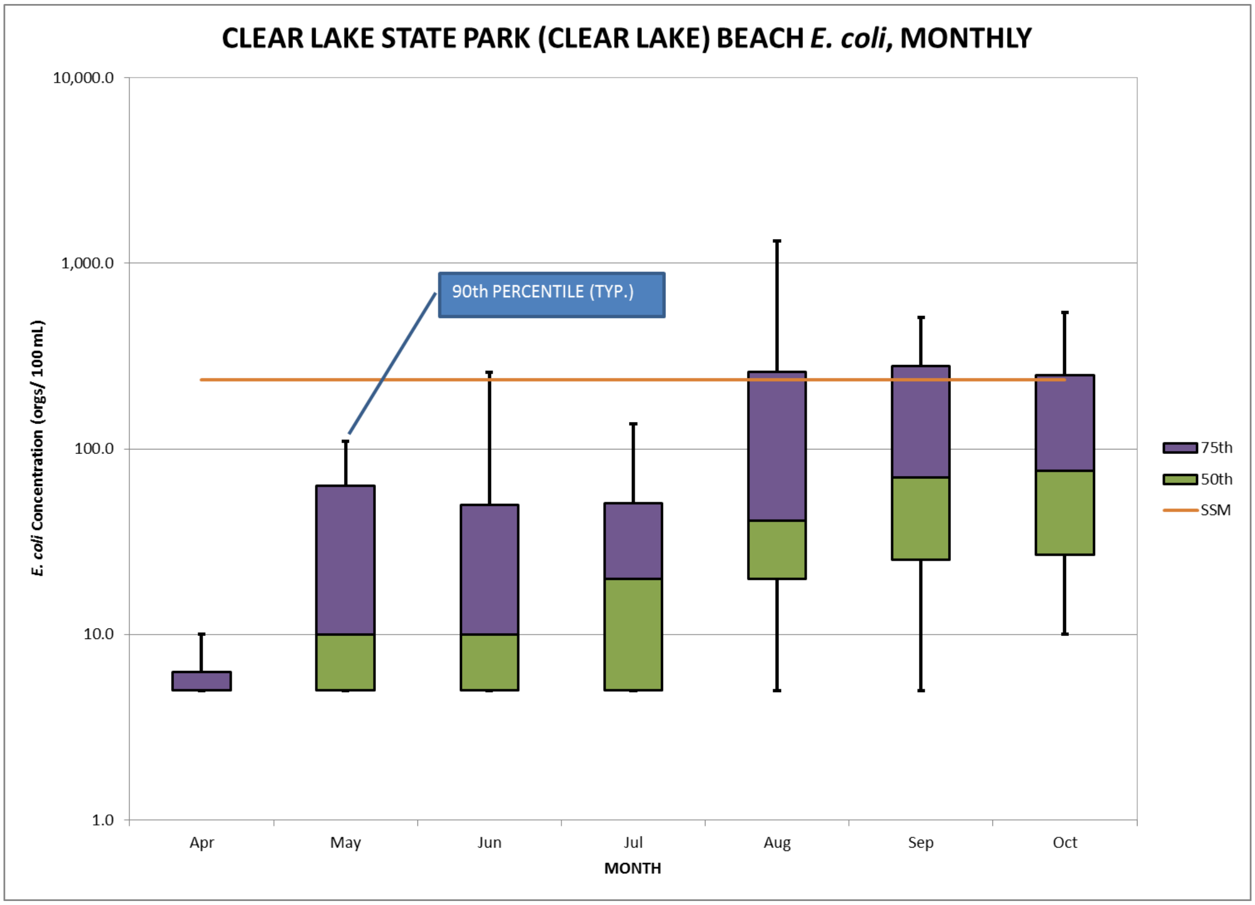


Figure 5-12. Monthly Box Plot, Clear Lake State Park.

From Figure 5-12 it can be seen that levels of bacteria are higher in the late summer and early fall with higher levels also occurring in June. The general trend is for bacteria levels to increase from spring into summer and stay elevated throughout the fall.

Review of the data indicates that summer and fall are the time and seasons where most of the focus and energy should be placed. However, the other months should not be neglected or ignored since they do have samples that exceed the SSM criterion.

5.2.1. TMDL Target

Selection of Environmental Conditions

The critical period for the impairment occurs in the recreational season of March 15 to November 15. The critical volume is the NSBV, which is adjacent to the beach area.

Waterbody Pollutant Loading Capacity

Attainment of the WQS to fully support primary contact recreation requires that the GM for *E. coli* concentrations be no greater than 126 orgs/ 100 mL and the SSM be not greater than 235 orgs/ 100 mL (Iowa Administrative Code 567, Chapter 61, Water Quality Standards for Class A1 uses). The methods used to develop the *E. coli* TMDL for the Clear Lake are based on the assumption that compliance with the SSM will coincide with attainment of the GM target. Therefore, the loading capacity of the TMDL is the maximum number of *E. coli* organisms that can be in the NSBV while meeting the SSM criterion of 235 orgs/ 100 mL.

Decision Criteria for WQS Attainment
The seasonal duration curve was constructed using daily sampling data. The SSM criterion was used to quantify the loading capacity of the NSBV, in terms of load (orgs/ 100 mL). Points above the red SSM line in Figures 5-13 and 5-14 represent violations of the WQS, whereas points below the line comply with WQS.

WQS will be attained in the NSBV when less than 10% of samples exceed the SSM criterion of 235 orgs/ 100 mL during the recreational season of March 15 – November 15.

5.2.2. Pollution Source Assessment

Departure from Load Capacity
The seasonal load curve and observed loads for the seasonal conditions are plotted in Figure 5-13 and Figure 5-14. This methodology enables calculation of a TMDL target for each season. However, the highest percent reduction of the three seasons will be used as the target reduction for all impaired seasons. It is assumed if the highest percent reduction rate is used and achieved that WQS will be attained for GM and SSM criterion for all seasons.

Allowance for Increases in Pollutant Loads
Based on current land use it is unlikely that any sources will be developed within the beach shed are of McIntosh Woods or Clear Lake State Parks.

5.2.3. Pollutant Allocations

Wasteload Allocations (WLA)
There are no point sources in the beach shed of McIntosh Woods or Clear Lake State Parks. Therefore, the WLA portion of this TMDL is zero.

Load Allocation (LA)
Nonpoint sources result from livestock, pets, wildlife, and humans that live, work, and play in and around the stream. Specific examples of potential nonpoint sources of bacteria include animals directly depositing into streams, manure applied to row crops, manure runoff from grazed land, non-permitted onsite wastewater systems, and natural sources such as wildlife.

Based on the results of the 2-year study presented in Chapter 2 of this WQIP the source of the impairment is from the near shore beach environment. Source of *E. coli* is from water fowl loafing on the beach and regeneration of *E. coli* in the sand environment.

Margin of Safety
An explicit margin of safety (MOS) of 10 percent is applied to the calculation of loading capacities in this TMDL. Additionally, targeting the GM in each flow condition, rather than only the overall GM, provides an implicit MOS by requiring WQS compliance across flow conditions.

Seasonal Load Curve
Figure 5-13 and Figure 5-14 are the seasonal load curves for the NSBV's at Clear Lake. Table 5-6 through Table 5-9 are the existing load estimates and TMDL summary for each NSBV. It is assumed that the NSVB is constant from year to year therefore the TMDL calculations are constant and the TMDL's can be presented as a concentration.

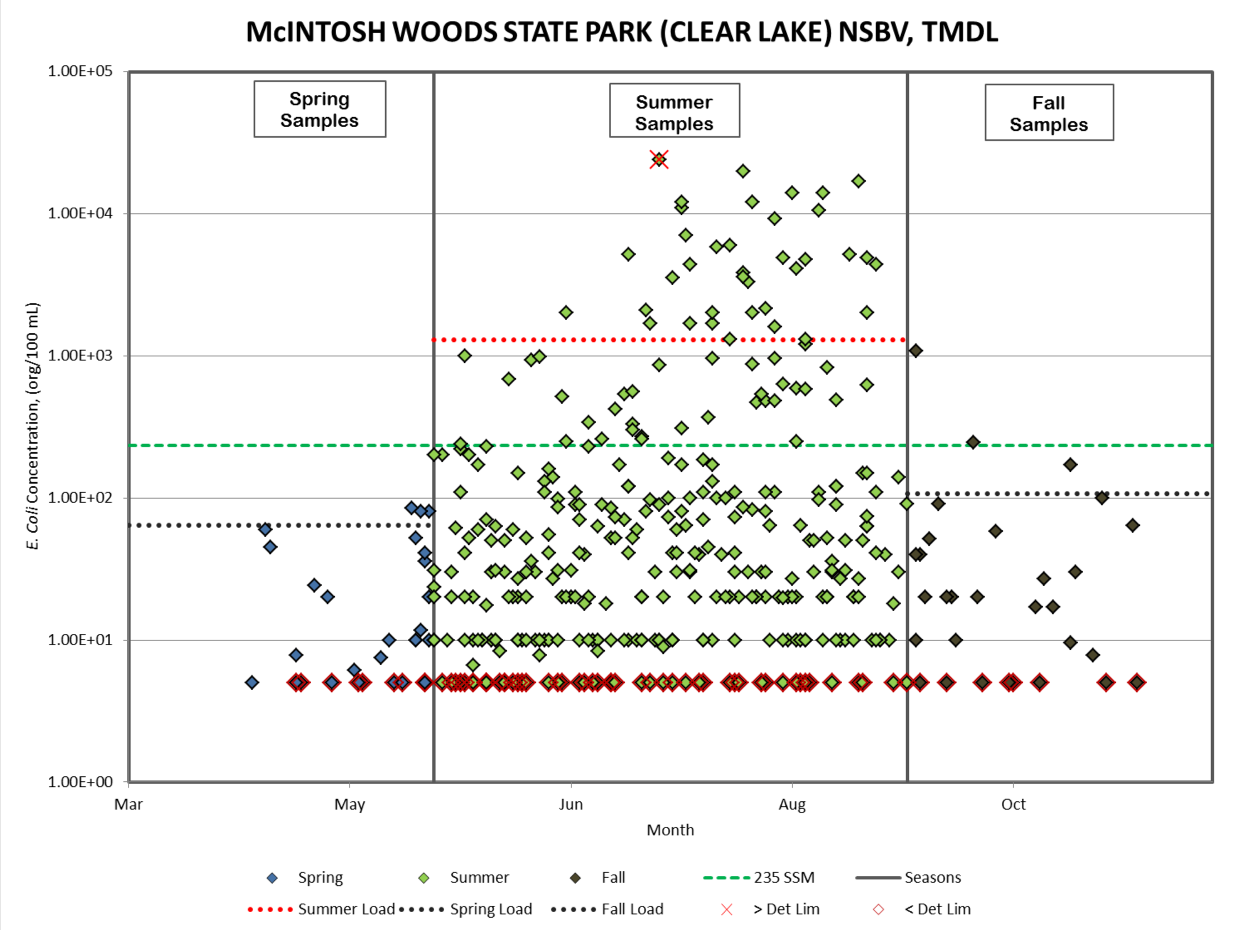


Figure 5-13. Seasonal Load Curve, McIntosh Woods, Near Shore Beach Volume.

Table 5-6. Existing Load Estimates for the NSBV at McIntosh Woods.

Load Summary	Seasonal Loads (org/ 100 mL)		
	Spring(1)	Summer	Fall(1)
Observed Load(2)	264.0	1,300.0	4,270.0
Departure	N/A	1,065.0	N/A
(% Reduction)	(0)	(81.9)	(0)

(1) Not assessed as impaired. Less than 10% of samples exceeded the SSM criterion of 235 orgs/ 100 mL.
(2) Observed load is the 90th percentile of water quality samples.

Table 5-7. TMDL Summary for the NSBV at McIntosh Woods.

	TMDL
TMDL (org/ 100 mL)	235
WLA (org/ 100 mL))	0.0
LA (org/ 100 mL)	211.5
MOS (org/ 100 mL)	23.5

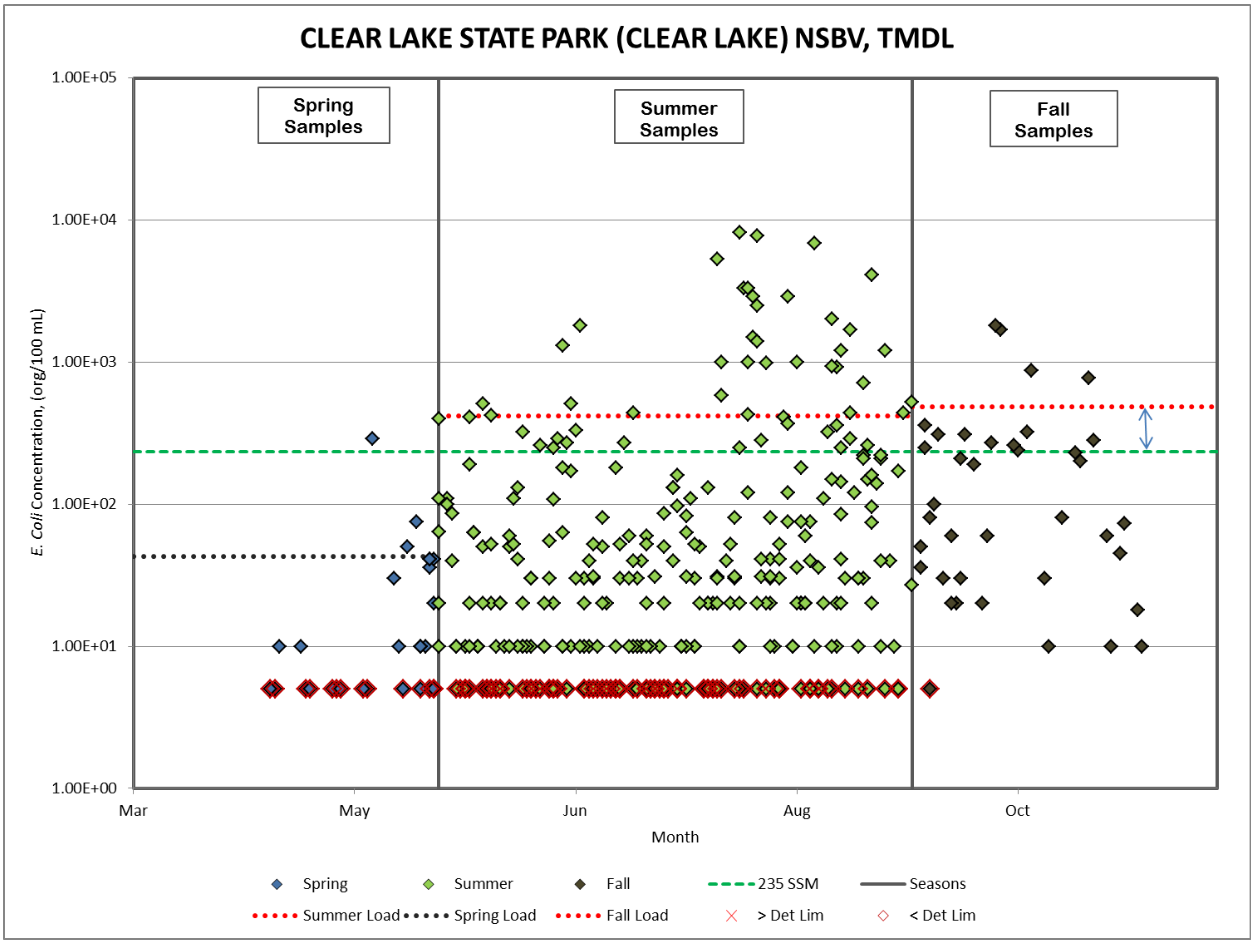


Figure 5-14. Seasonal Load Curve, Clear Lake, Near Shore Beach Volume.

Table 5-8. Existing Load Estimates for the NSBV at Clear Lake.

Load Summary	Seasonal Loads (org/ 100 mL)		
	Spring	Summer	Fall
Observed Load(1)	42.8	420.0	483.0
Departure	N/A	185.0	248.0
(% Reduction)	(0)	(44.0)	(51.3)

(1) Observed load is the 90th percentile of water quality samples.

Table 5-9. TMDL Summary for the NSBV at Clear Lake.

	TMDL
TMDL (org/ 100 mL)	235
WLA (org/ 100 mL))	0.0
LA (org/ 100 mL)	211.5
MOS (org/ 100 mL)	23.5

5.2.4. TMDL Summary

This TMDL is based on meeting the water quality criteria for primary contact and children's recreation in Clear Lake. Although the WQS are based on *E. coli* concentration, the TMDL is also expressed as a load, in light of the November 2006 EPA memorandum. The following equation represents the total maximum daily load (TMDL) and its components:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

Where: TMDL = total maximum daily load
LC = loading capacity
ΣWLA = sum of wasteload allocations (point sources)
ΣLA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

Once the loading capacity, waste load allocations, load allocations, and margin of safety are determined Clear Lake, the general equation above can be expressed for each NSBV and season for *E. coli* as the allowable daily load. The mass loadings for McIntosh Woods State Park and Clear Lake State Park beach areas are presented in Table 5-10.

Table 5-10. Summary of Clear Lake TMDL.

NSBV	TMDL (orgs/day)	WLA (orgs/day)	LA (orgs/day)	MOS (orgs/day)
McIntosh Woods	6.33E+06	0.00E+00	5.70E+06	6.33E+05
Clear Lake	3.55E+07	0.00E+00	3.20E+07	3.55E+06

Appendix 5.A – Water Quality Data

Table 5.A-1. Water Quality Sampling Data, Beach Monitoring, Clear Lake, SITE ID 21170001.

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/2/1999	< 10[2]	6/11/2001	10	9/17/2002	20
6/8/1999	< 10[2]	6/18/2001	< 10[2]	9/24/2002	60
6/16/1999	10	6/25/2001	< 10[2]	10/1/2002	240
6/21/1999	< 10[2]	7/2/2001	< 10[2]	10/8/2002	10
6/29/1999	< 10[2]	7/9/2001	< 10[2]	10/15/2002	200
7/6/1999	< 10[2]	7/16/2001	< 10[2]	10/22/2002	10
7/12/1999	< 10[2]	7/23/2001	130	10/29/2002	10
7/20/1999	10	7/24/2001	< 10[2]	4/15/2003	< 10[2]
7/26/1999	< 10[2]	7/30/2001	< 10[2]	4/22/2003	10
8/3/1999	< 10[2]	8/6/2001	20	4/29/2003	< 10[2]
8/11/1999	10	8/13/2001	20	5/6/2003	< 10[2]
8/16/1999	10	8/16/2001	6,900	5/13/2003	30
8/23/1999	< 10[2]	8/20/2001	< 10[2]	5/20/2003	10
8/31/1999	10	8/27/2001	710	5/27/2003	10
9/7/1999	27	9/4/2001	< 10[2]	6/3/2003	< 10[2]
9/14/1999	30	9/10/2001	250	6/10/2003	130
5/22/2000	< 10[2]	4/16/2002	< 10[2]	6/17/2003	55
5/30/2000	< 10[2]	4/23/2002	< 10[2]	6/24/2003	1,800
6/5/2000	10	4/30/2002	< 10[2]	7/1/2003	< 10[2]
6/12/2000	< 10[2]	5/7/2002	< 10[2]	7/8/2003	40
6/19/2000	< 10[2]	5/14/2002	10	7/15/2003	40
6/26/2000	10	5/21/2002	< 10[2]	7/22/2003	< 10[2]
7/5/2000	60	5/28/2002	< 10[2]	7/29/2003	< 10[2]
7/10/2000	< 10[2]	6/4/2002	420	8/5/2003	< 10[2]
7/17/2000	10	6/11/2002	320	8/12/2003	36
7/24/2000	20	6/18/2002	250	8/19/2003	< 10[2]
7/31/2000	< 10[2]	6/25/2002	20	8/26/2003	10
8/7/2000	< 10[2]	7/2/2002	180	9/1/2003	< 10[2]
8/14/2000	20	7/9/2002	60	9/9/2003	36
8/21/2000	10	7/16/2002	160	9/16/2003	20
8/28/2000	< 10[2]	7/23/2002	< 10[2]	9/23/2003	20
9/4/2000	< 10[2]	7/30/2002	250	9/30/2003	260
9/11/2000	< 10[2]	8/6/2002	30	10/7/2003	30
9/18/2000	30	8/13/2002	20	10/14/2003	230
5/21/2001	36	8/20/2002	10	10/21/2003	60
5/22/2001	20	8/27/2002	220	10/28/2003	18
5/29/2001	< 10[2]	9/3/2002	10	5/25/2004	110
6/4/2001	< 10[2]	9/10/2002	360	6/1/2004	10
6/7/2004	10	9/26/2005	1,800	8/6/2007	41
6/14/2004	< 10[2]	10/3/2005	320	8/13/2007	< 10[2]

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/21/2004	270	10/17/2005	770	8/20/2007	933
6/28/2004	< 10(2)	10/24/2005	45	8/22/2007	144
7/6/2004	440	4/17/2006	10	8/27/2007	30
7/12/2004	10	4/24/2006	< 10(2)	8/29/2007	20
7/19/2004	110	5/1/2006	< 10(2)	5/19/2008	< 10(2)
7/26/2004	1,000	5/8/2006	290	5/27/2008	10
8/2/2004	1,500	5/15/2006	< 10(2)	6/2/2008	20
8/9/2004	410	5/22/2006	< 10(2)	6/9/2008	110
8/17/2004	36	5/29/2006	< 10(2)	6/17/2008	30
8/23/2004	30	6/5/2006	< 10(2)	6/23/2008	330
8/30/2004	140	6/12/2006	10	6/25/2008	30
9/7/2004	520	6/19/2006	290	6/30/2008	< 10(2)
9/13/2004	310	6/26/2006	40	7/2/2008	< 10(2)
9/21/2004	190	7/3/2006	30	7/7/2008	30
9/27/2004	1,700	7/10/2006	10	7/9/2008	20
10/4/2004	870	7/17/2006	10	7/14/2008	< 10(2)
10/11/2004	80	7/24/2006	< 10(2)	7/16/2008	< 10(2)
10/18/2004	280	7/31/2006	3,300	7/21/2008	50
10/25/2004	73	8/7/2006	10	7/23/2008	20
5/16/2005	50	8/14/2006	60	7/28/2008	20
5/23/2005	64	8/21/2006	920	7/30/2008	20
5/29/2005	10	8/28/2006	150	8/4/2008	280
6/6/2005	< 10(2)	9/4/2006	170	8/6/2008	80
6/13/2005	10	9/11/2006	80	8/11/2008	10
6/20/2005	1,300	9/18/2006	210	8/13/2008	20
6/27/2005	30	9/25/2006	270	8/20/2008	150
7/4/2005	270	5/22/2007	41	8/26/2008	30
7/11/2005	< 10(2)	5/30/2007	410	9/2/2008	40
7/18/2005	82	6/4/2007	20	9/9/2008	50
7/25/2005	5,300	6/11/2007	10	9/16/2008	60
8/3/2005	2,500	6/18/2007	108	5/19/2009	10
8/8/2005	30	6/25/2007	10	5/26/2009	40
8/15/2005	40	7/2/2007	< 10(2)	6/1/2009	10
8/22/2005	250	7/9/2007	52	6/3/2009	< 10(2)
8/29/2005	4,100	7/16/2007	< 10(2)	6/8/2009	50
9/5/2005	440	7/23/2007	< 10(2)	6/10/2009	10
9/12/2005	100	7/30/2007	8,200	6/15/2009	< 10(2)
9/19/2005	310	8/1/2007	426	6/17/2009	< 10(2)
6/22/2009	10	5/31/2011	63	7/30/2013	10
6/24/2009	10	6/6/2011	20	8/6/2013	31
6/29/2009	80	6/13/2011	30	8/13/2013	75
7/6/2009	40	6/20/2011	63	8/20/2013	2,000

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
7/8/2009	10	6/28/2011	10	8/21/2013	360
7/13/2009	20	7/5/2011	30	8/27/2013	210
7/15/2009	130	7/13/2011	< 10(2)	5/19/2014	10
7/20/2009	10	7/18/2011	10	5/27/2014	< 10(2)
7/22/2009	< 10(2)	7/25/2011	31	6/2/2014	510
7/27/2009	40	8/2/2011	2,900	6/9/2014	52
7/29/2009	30	8/4/2011	31	6/16/2014	10
8/5/2009	20	8/8/2011	< 10(2)	6/23/2014	30
8/10/2009	120	8/15/2011	75	6/30/2014	20
8/12/2009	20	8/22/2011	85	7/7/2014	< 10(2)
8/17/2009	< 10(2)	8/31/2011	210	7/15/2014	130
8/24/2009	1700	5/21/2012	41	7/21/2014	20
8/26/2009	30	5/30/2012	20	7/28/2014	52
9/1/2009	1,200	6/4/2012	< 10(2)	8/4/2014	41
5/25/2010	100	6/11/2012	20	8/13/2014	180
6/2/2010	50	6/18/2012	< 10(2)	8/18/2014	20
6/8/2010	60	6/26/2012	< 10(2)	8/25/2014	120
6/15/2010	260	7/3/2012	< 10(2)	5/18/2015	75
6/17/2010	< 10(2)	7/9/2012	10	5/26/2015	86
6/22/2010	510	7/17/2012	10	6/1/2015	10
6/29/2010	50	7/23/2012	< 10(2)	6/10/2015	41
7/7/2010	10	7/30/2012	10	6/16/2015	20
7/13/2010	50	8/6/2012	10	6/22/2015	170
7/20/2010	30	8/14/2012	20	6/29/2015	20
7/26/2010	580	8/21/2012	20	7/6/2015	10
7/29/2010	80	8/28/2012	260	7/13/2015	< 10(2)
8/3/2010	7,700	5/21/2013	41	7/20/2015	52
8/5/2010	990	5/29/2013	< 10(2)	7/29/2015	31
8/10/2010	2,900	6/4/2013	52	8/3/2015	20
8/12/2010	1,000	6/11/2013	< 10(2)	8/10/2015	370
8/17/2010	< 10(2)	6/18/2013	20	8/18/2015	110
8/19/2010	320	6/25/2013	< 10(2)	8/24/2015	440
8/24/2010	290	7/2/2013	10	8/31/2015	220
8/26/2010	< 10(2)	7/9/2013	< 10(2)	5/23/2016	10
8/31/2010	40	7/16/2013	97	5/31/2016	63
5/23/2011	110	7/23/2013	20	6/8/2016	10
6/13/2016	< 10(2)	6/13/2017	30	6/27/2018	52
6/20/2016	180	6/20/2017	10	7/3/2018	< 10(2)
6/27/2016	31	6/27/2017	< 10(2)	7/11/2018	< 10(2)
7/5/2016	10	7/3/2017	52	7/18/2018	31
7/13/2016	86	7/11/2017	31	7/25/2018	30
7/18/2016	63	7/18/2017	< 10(2)	8/1/2018	3,300

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
7/25/2016	20	7/25/2017	< 10(2)	8/8/2018	52
8/1/2016	1,000	8/1/2017	120	8/15/2018	< 10(2)
8/3/2016	1,400	8/8/2017	< 10(2)	8/22/2018	20
8/8/2016	41	8/15/2017	< 10(2)	8/29/2018	160
8/10/2016	75	8/22/2017	41		
8/15/2016	< 10(2)	8/29/2017	96	Min =	5
8/22/2016	1,200	5/23/2018	400	1st Quartile =	20
8/29/2016	74	5/30/2018	190	Median =	41
5/23/2017	20	6/6/2018	20	3rd Quartile =	150
5/30/2017	10	6/13/2018	< 10(2)	Max =	20,000
6/6/2017	< 10(2)	6/20/2018	10	Mean =	240

(1) Unless noted samples collected by the Iowa DNR as part of Ambient water quality monitoring.
(2) E. coli was not detectable. The minimum detection limit is 10 org/100 mL. Consequently, 5 org/100 mL was used in calculations.

Table 5.A-2. Water Quality Sampling Data, Beach Monitoring, McIntosh Woods, SITE ID 21170002.

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/1/1999	< 10(2)	6/14/2001	930	9/24/2002	< 10(2)
6/8/1999	< 10(2)	6/18/2001	10	10/1/2002	< 10(2)
6/16/1999	10	6/25/2001	70	10/8/2002	27
6/21/1999	< 10(2)	7/2/2001	< 10(2)	10/15/2002	30
6/29/1999	< 10(2)	7/9/2001	20	10/22/2002	< 10(2)
7/6/1999	10	7/16/2001	10	10/29/2002	< 10(2)
7/12/1999	10	7/19/2001	64	4/15/2003	60
7/20/1999	100	7/23/2001	< 10(2)	4/22/2003	< 10(2)
7/26/1999	99	7/25/2001	10	4/29/2003	20
8/3/1999	82	7/30/2001	< 10(2)	5/6/2003	< 10(2)
8/11/1999	10	8/6/2001	< 10(2)	5/13/2003	10
8/16/1999	50	8/13/2001	< 10(2)	5/20/2003	80
8/23/1999	27	8/15/2001	10	5/27/2003	30
8/31/1999	110	8/27/2001	27	6/3/2003	10
9/7/1999	91	9/4/2001	18	6/10/2003	20
9/14/1999	91	9/10/2001	40	6/17/2003	10
5/22/2000	80	4/16/2002	45	6/24/2003	90
5/30/2000	< 10(2)	4/23/2002	< 10(2)	7/1/2003	18
6/5/2000	10	4/30/2002	< 10(2)	7/8/2003	10
6/12/2000	< 10(2)	5/7/2002	< 10(2)	7/15/2003	100
6/19/2000	27	5/14/2002	< 10(2)	7/22/2003	< 10(2)
6/26/2000	40	5/21/2002	< 10(2)	7/29/2003	< 10(2)
7/5/2000	70	5/28/2002	< 10(2)	8/5/2003	30
7/10/2000	2,100	6/4/2002	70	8/12/2003	27
7/17/2000	30	6/11/2002	20	8/19/2003	20
7/24/2000	45	6/18/2002	55	8/26/2003	20
7/31/2000	20	6/25/2002	< 10(2)	9/1/2003	10
8/7/2000	10	7/2/2002	< 10(2)	9/9/2003	10
8/14/2000	< 10(2)	7/9/2002	< 10(2)	9/16/2003	20
8/21/2000	36	7/16/2002	10	9/23/2003	20
8/28/2000	150	7/23/2002	10	9/30/2003	< 10(2)
9/5/2000	30	7/30/2002	110	10/7/2003	< 10(2)
9/11/2000	20	8/6/2002	80	10/14/2003	170
9/18/2000	10	8/13/2002	20	10/21/2003	100
5/21/2001	36	8/20/2002	20	10/28/2003	64
5/29/2001	< 10(2)	8/27/2002	< 10(2)	5/25/2004	200
6/4/2001	< 10(2)	9/3/2002	10	6/1/2004	10
6/5/2001	30	9/10/2002	< 10(2)	6/7/2004	< 10(2)
6/11/2001	< 10(2)	9/17/2002	20	6/14/2004	36
6/21/2004	20	8/7/2006	64	8/11/2008	20
6/28/2004	10	8/14/2006	64	8/13/2008	590

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
7/6/2004	120	8/21/2006	30	8/20/2008	20
7/12/2004	30	8/28/2006	50	8/26/2008	20
7/19/2004	< 10(2)	9/4/2006	< 10(2)	9/2/2008	40
7/26/2004	20	5/22/2007	20	9/9/2008	40
8/2/2004	30	5/30/2007	10	9/16/2008	< 10(2)
8/9/2004	20	6/4/2007	< 10(2)	5/19/2009	10
8/16/2004	< 10(2)	6/11/2007	10	5/26/2009	10
8/23/2004	10	6/18/2007	< 10(2)	6/1/2009	20
8/30/2004	10	6/25/2007	10	6/3/2009	10
9/7/2004	< 10(2)	7/2/2007	52	6/8/2009	50
5/16/2005	< 10(2)	7/9/2007	10	6/10/2009	60
5/23/2005	10	7/16/2007	41	6/15/2009	10
5/29/2005	220	7/23/2007	185	6/17/2009	110
6/6/2005	10	7/30/2007	73	6/22/2009	20
6/13/2005	< 10(2)	8/6/2007	20	6/24/2009	20
6/20/2005	< 10(2)	8/13/2007	10	6/29/2009	10
6/27/2005	20	8/20/2007	52	7/6/2009	120
7/4/2005	170	8/27/2007	17,000	7/8/2009	60
7/11/2005	< 10(2)	8/29/2007	2,000	7/13/2009	10
7/18/2005	80	5/19/2008	10	7/15/2009	190
7/25/2005	130	5/27/2008	< 10(2)	7/20/2009	30
8/3/2005	870	6/2/2008	60	7/22/2009	40
8/8/2005	110	6/9/2008	680	7/27/2009	40
8/15/2005	< 10(2)	6/17/2008	130	7/29/2009	20
8/22/2005	90	6/23/2008	20	8/5/2009	< 10(2)
8/29/2005	150	6/25/2008	90	8/10/2009	10
9/5/2005	140	6/30/2008	90	8/12/2009	20
5/22/2006	10	7/2/2008	10	8/17/2009	30
5/29/2006	110	7/7/2008	330	8/24/2009	10
6/5/2006	50	7/9/2008	10	9/1/2009	10
6/12/2006	10	7/14/2008	20	5/25/2010	< 10(2)
6/19/2006	140	7/16/2008	10	6/2/2010	10
6/26/2006	18	7/21/2008	20	6/8/2010	30
7/3/2006	73	7/23/2008	70	6/15/2010	30
7/10/2006	80	7/28/2008	100	6/22/2010	2,000
7/17/2006	60	7/30/2008	10	6/29/2010	10
7/24/2006	370	8/4/2008	20	7/7/2010	300
7/31/2006	< 10(2)	8/6/2008	110	7/13/2010	90
7/20/2010	4,400	5/21/2013	41	6/10/2015	< 10(2)
7/26/2010	5,800	5/29/2013	240	6/16/2015(3)	8
8/3/2010	2,000	6/4/2013	230	6/16/2015	10
8/10/2010	< 10(2)	6/11/2013	10	6/22/2015	250

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
8/12/2010	14,000	6/18/2013	10	6/24/2015	110
8/17/2010	50	6/25/2013	41	6/29/2015(3)	8
8/19/2010	10	7/2/2013	85	6/29/2015	63
8/24/2010	50	7/9/2013	270	7/6/2015	41
8/31/2010	10	7/16/2013	< 10(2)	7/13/2015	860
5/23/2011	200	7/23/2013	110	7/14/2015(3)	9
5/31/2011	200	7/30/2013	41	7/15/2015	73
6/6/2011	63	8/6/2013	480	7/20/2015	31
6/13/2011	30	8/13/2013	250	7/29/2015(3)	5,984
6/20/2011	98	8/20/2013	830	7/29/2015	1,300
6/28/2011	< 10(2)	8/21/2013	31	8/3/2015	20
7/5/2011	10	8/27/2013	20	8/5/2015	540
7/13/2011	10	5/19/2014	52	8/10/2015(3)	20
7/18/2011	170	5/27/2014	20	8/10/2015	630
7/25/2011	960	6/2/2014	170	8/18/2015	97
8/2/2011	3,300	6/9/2014	20	8/19/2015	14,000
8/4/2011	470	6/16/2014	980	8/24/2015	31
8/8/2011	960	6/18/2014	160	8/26/2015(3)	10
8/15/2011	1,200	6/23/2014	31	8/31/2015	4,400
8/22/2011	10	6/30/2014	260	9/9/2015(3)	1,084
8/31/2011	41	7/7/2014	52	9/22/2015(3)	245
5/21/2012	< 10(2)	7/9/2014	260	10/6/2015(3)	17
5/30/2012	20	7/14/2014	< 10(2)	10/14/2015(3)	10
6/4/2012	< 10(2)	7/21/2014	41	10/19/2015(3)	8
6/11/2012	150	7/28/2014	20	4/12/2016(3)	5
6/18/2012	41	8/4/2014	20	4/26/2016(3)	24
6/26/2012	< 10(2)	8/13/2014	4,100	5/11/2016(3)	8
7/3/2012	< 10(2)	8/18/2014	110	5/23/2016(3)	23
7/9/2012	20	8/25/2014	5,200	5/23/2016	31
7/17/2012	41	4/22/2015(3)	8	5/31/2016	52
7/23/2012	10	5/5/2015(3)	6	6/7/2016(3)	8
7/30/2012	30	5/18/2015	85	6/8/2016	< 10(2)
8/6/2012	30	5/20/2015(3)	12	6/13/2016	10
8/14/2012	10	5/28/2015	61	6/20/2016	31
8/21/2012	< 10(2)	6/1/2015(3)	7	6/21/2016(3)	518
8/28/2012	< 10(2)	6/1/2015	< 10(2)	6/27/2016	230
7/5/2016	540	5/30/2017	41	7/3/2018	420
7/6/2016(3)	5,171	6/6/2017	10	7/11/2018	97
7/7/2016	560	6/13/2017	20	7/16/2018(3)	3,546
7/13/2016	< 10(2)	6/20/2017	10	7/18/2018	12,000
7/18/2016	11,000	6/27/2017	10	7/25/2018	170
7/19/2016(3)	7,028	7/3/2017	52	8/1/2018	86

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
7/20/2016	1,700	7/11/2017	1,700	8/6/2018(3)	2,151
7/25/2016	1,700	7/18/2017	310	8/8/2018	480
8/1/2016(3)	3,817	7/25/2017	2,000	8/15/2018(3)	4,748
8/1/2016	3,600	8/1/2017	20,000	8/15/2018	10
8/3/2016	12,000	8/8/2017	1,600	8/22/2018	490
8/8/2016	9,200	8/15/2017	1,300	8/29/2018(3)	4,928
8/10/2016	4,900	8/22/2017	120	8/29/2018	620
8/15/2016	580	8/29/2017	74		
8/18/2016(3)	10,565	5/23/2018	20		
8/22/2016	120	5/30/2018	1,000		
8/29/2016(3)	63	6/4/2018(3)	18	Min =	5
8/29/2016	63	6/6/2018	31	1st Quartile =	20
9/12/2016(3)	52	6/11/2018(3)	27	Median =	41
9/27/2016(3)	58	6/13/2018	52	3rd Quartile =	150
10/10/2016(3)	17	6/20/2018	86	Max =	20,000
5/23/2017	10	6/27/2018	340	Mean =	595

(1) Unless noted samples collected by the Iowa DNR as part of Ambient water quality monitoring.
(2) E. coli was not detectable. The minimum detection limit is 10 org/100 mL. Consequently, 5 org/100 mL was used in calculations.
(3) Samples collected by Iowa DNR as part of 2015 study.

6. Nine Eagles Lake TMDL

6.1. Description and History of Nine Eagles Lake

Nine Eagles Lake, IA 05-GRA-1361, is located in Hamilton Township, Decatur County, Iowa approximately 1 mile northwest of Pleasanton, 7 miles east of Lamoni, and 3.5 miles southeast of Davis City. The lake opened in 1940 and is located within 1,166 acres of conservation and recreation land owned and operated by the Iowa DNR. The lake and land surrounding it provide fishing, camping, hiking and other outdoor recreational activities for the Public.

The lake has a watershed area of 1,111 acres, a maximum depth of 32.4 feet, a shore length of approximately 2.65 miles, and an approximate volume of 730 acre-feet. Figure 6-1 is an aerial photograph with the boundaries of the watershed. Table 6-1 is a summary of the lake and watershed properties.

Table 6-1. Nine Eagles Watershed and Lake Information.

Waterbody Name	Nine Eagles Lake
Waterbody ID	IA 05-GRA-1361
12 Digit Hydrologic Unit Code (HUC)	102801020604
HUC-12 Name	Jefferies Creek-Thompson River
Location	Sections 17 & 18, T67N, R25W, Decatur County Iowa
Water Quality Standard Designated Uses	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life HH Human Health
Tributaries	Unnamed Tributaries
Receiving Waterbody	Unnamed Tributary to Thompson River
Watershed Area	1,111 acres
Lake Surface Area	60 acres
Maximum Depth	32.4 feet
Volume	730 ac-feet
Length of Shoreline	2.65 miles
Watershed/Lake Area Ratio	18.5:1

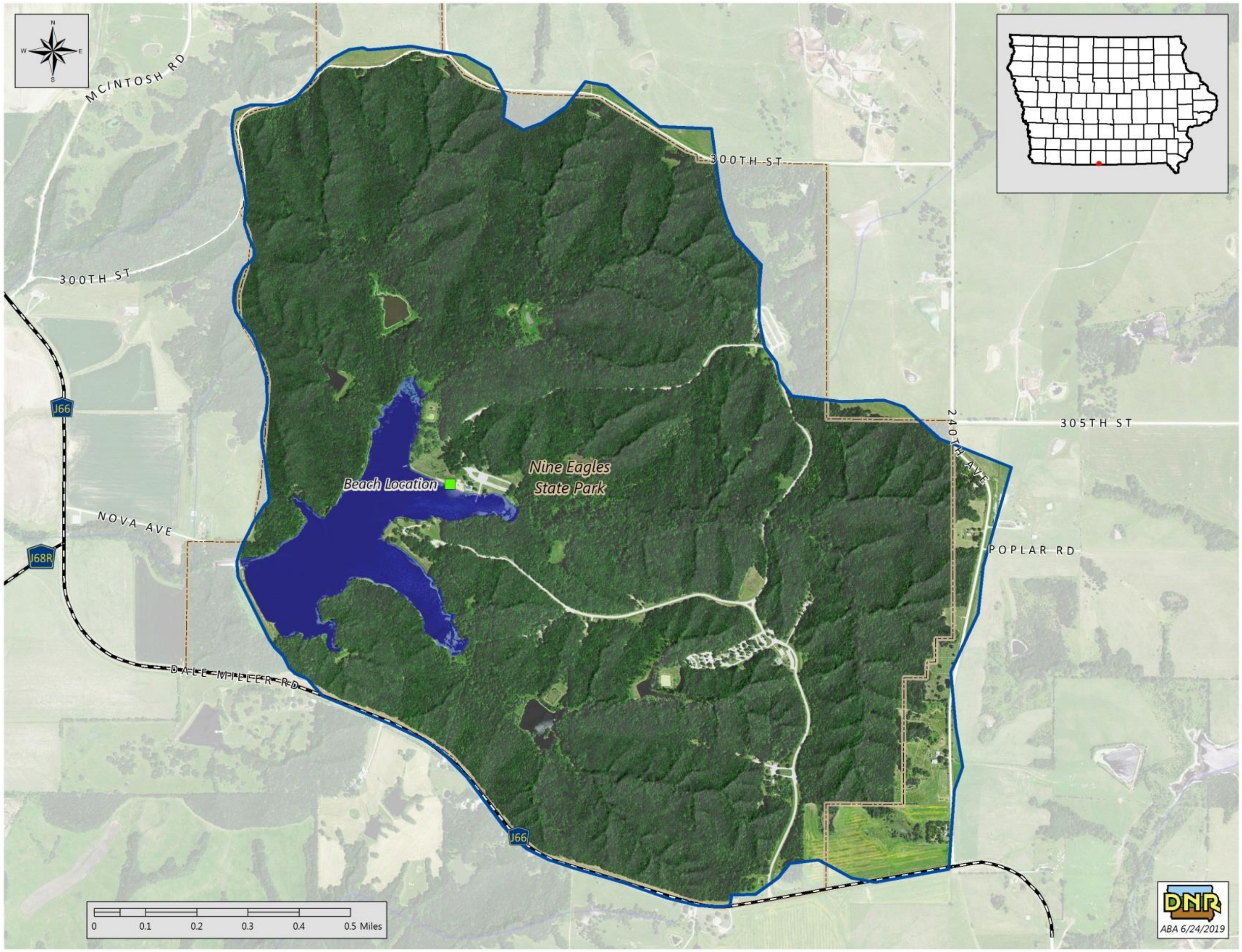


Figure 6-1. Nine Eagles Lake Watershed.

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using the 2014 USDA Cropland Data Layer (USDA, National Agricultural Statistics Service). The predominate land use is forested land (Forest Bottomland, Forest Deciduous) making up approximately 80.4% (1.0% bottomland, 79.3% deciduous) (Table 6-2). The seven land uses shown in Table 6-2 were aggregated from the fourteen land uses in the cropland data layer as shown in the description column. Figure 6-2 shows the distribution of the various land uses throughout the Nine Eagles Lake watershed in a pie-chart.

Table 6-2. Nine Eagles Watershed Land Uses.

Land Use	Description	Area (AC)	Percent of total
Water/Wetland	Water and Wetlands	80	7.2%
Forested	Bottomland, Coniferous, Deciduous	894	80.4%
Grassland	Ungrazed, Grazed, & CRP-	59	5.3%
Alfalfa/Hay	Perennial Hay Crop-	0	0.0%
Row crop	Corn, Soybeans, & other	16	1.4%
Roads	Roads Lightly Developed Urban	55	5.0%
Urban	Intensively Developed Urban	8	0.7%
Total		1,112	100.0%

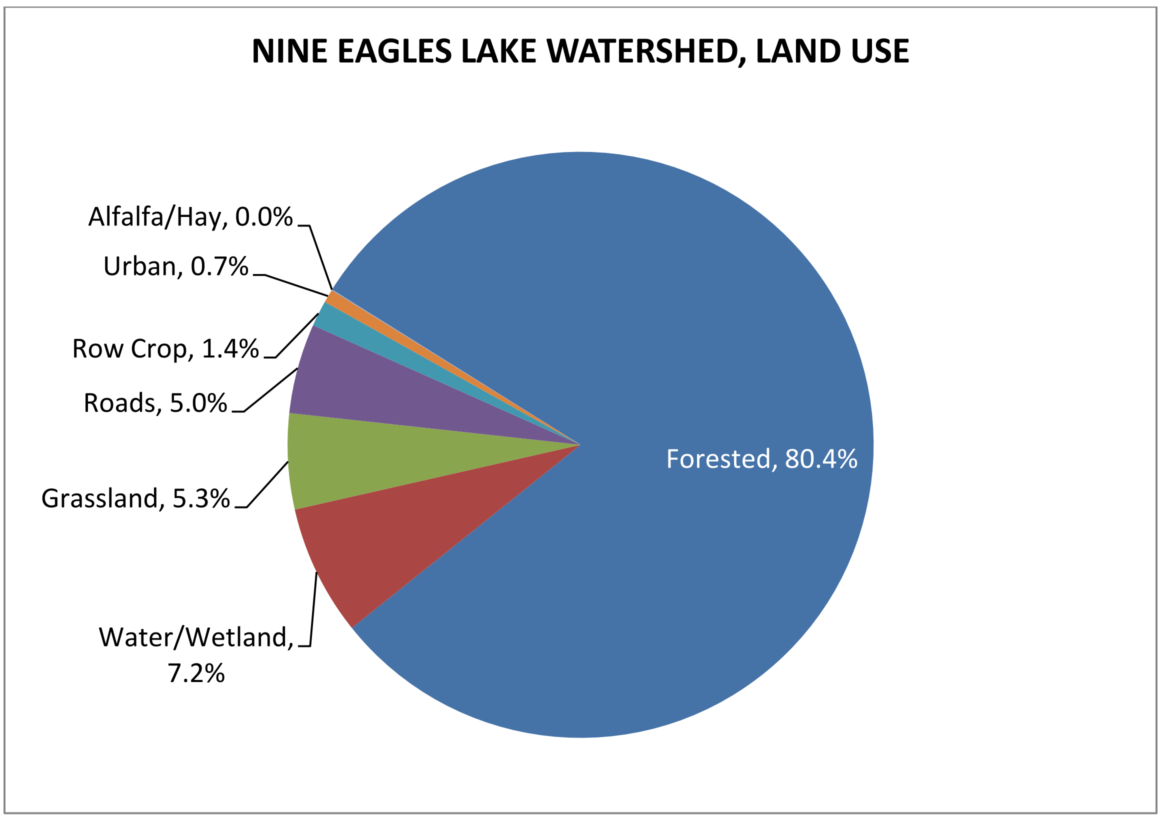


Figure 6-2. Land Use Composition of the Nine Eagles Lake Watershed.

Hydrology, Soils, Climate, Topography

From data obtained from the NRCS, there are 5 main soils types in this watershed. No soil type makes up a majority in the area. The top three soil types in the watershed are Lindley, Keswick and the Cantril-Coppock-Nodaway complex, which makes up 78.9% of the soil types in the watershed. The topography for the Nine Eagles Lake watershed consists of rolling hills with interfluvial regions of wooded area too steep for crops typical of the Southern Iowa Drift Plain landform region that it occupies.

The average rainfall for Hickory Grove Lake in Story County is 40.4 inches with the majority falling between April and October. Lake evapotranspiration averages 33.2 inches per year with more occurring in dryer years on average. Figure 6-3 shows the annual rainfall and reference evapotranspiration from 2002 to 2018. Figure 6-4 shows the monthly average relationship between watershed evapotranspiration and rainfall. In some drier summer months evapotranspiration may exceed rainfall, leading to a deficit in the water budget for the watershed.

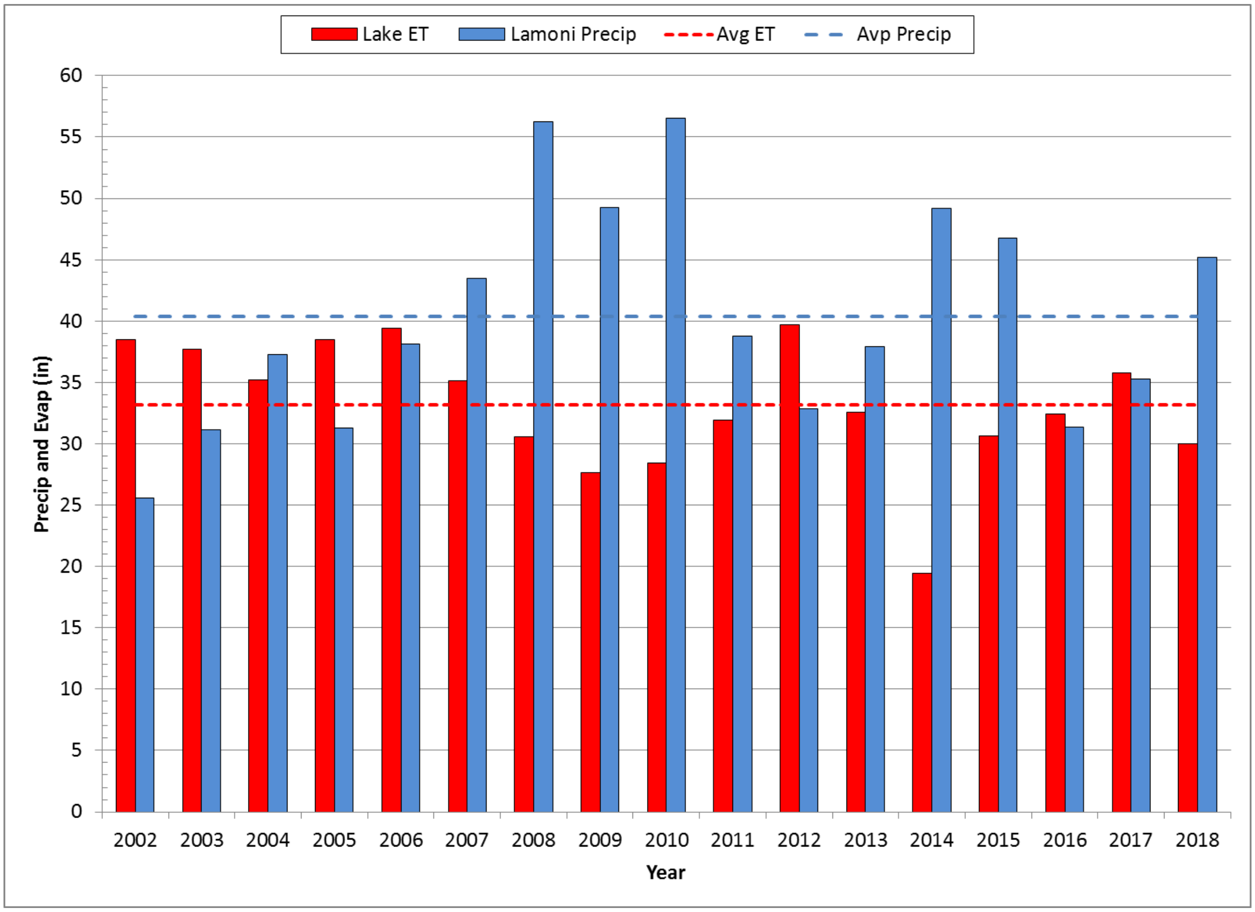


Figure 6-3. Annual Rainfall and Estimated Evapotranspiration Totals, Nine Eagles Watershed.

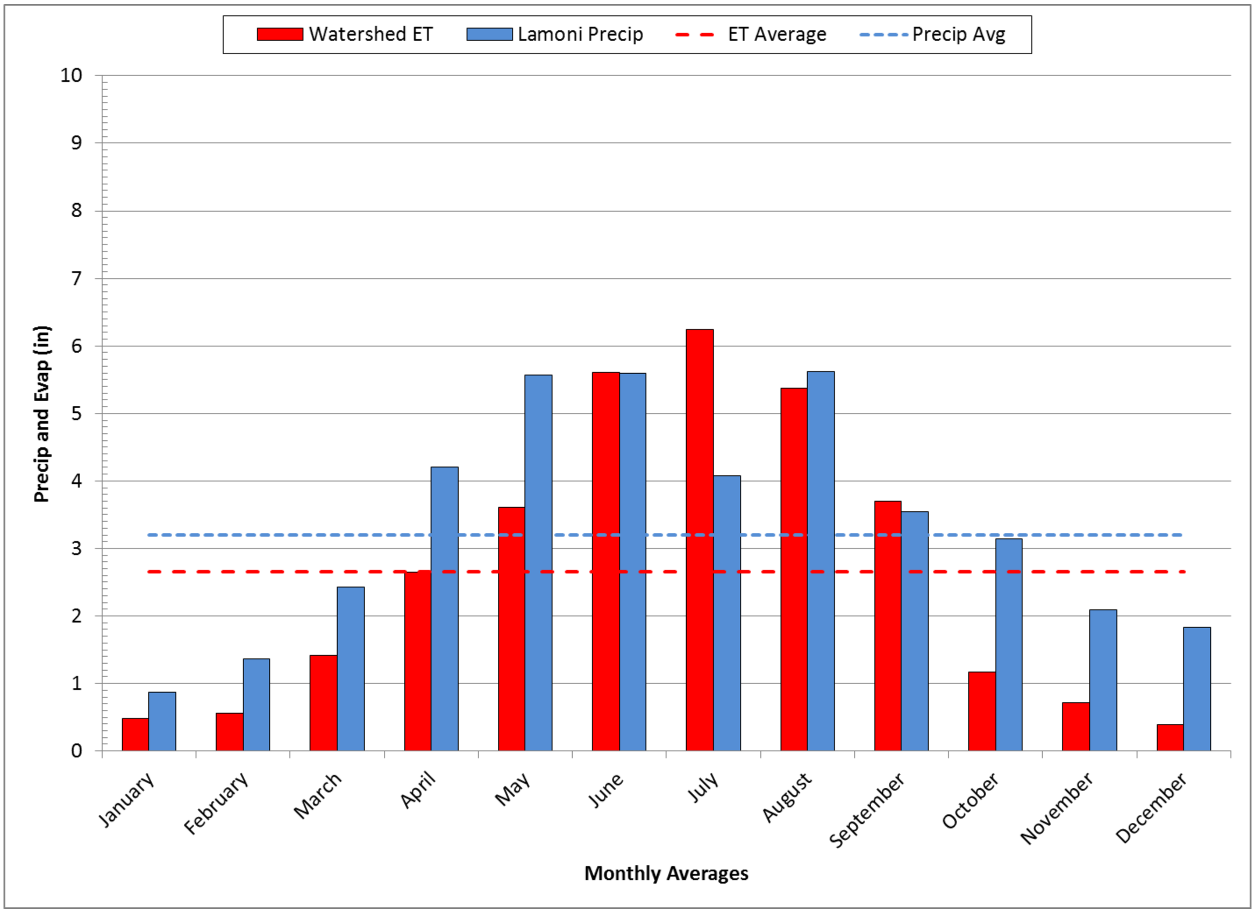


Figure 6-4. Monthly Rainfall and Estimated Evapotranspiration Totals, Nine Eagles Watershed.

6.2. TMDL for Nine Eagles Lake Beach.

The WQIP has provided general background information around the impaired lake. However, the sampling and monitoring of the lake that resulted in the impairment are located in the swimming zone of the *Nine Eagles State* Park. In addition, the data presented in Chapter 2 demonstrate that the source of the impairment comes for the beach area and not from the general watershed area of the lake.

Consequently, the TMDL will focus on the beach shed area and the swimming zone that it drains to.

Problem Identification

Nine Eagles Lake, IA 05-GRA-1361, was included on the 2006 impaired waters (303(d)) list for not fully supporting Class A1 (primary contact recreation) uses due to the presence of high levels of *E. coli*. Samples were collected during the recreational season (March 15 – November 15) between 2004 – 2018 as part of the state's ambient water quality monitoring and assessment program.

In 2015 and 2016 additional water quality samples were collected by the Iowa DNR to study and assess the relationships between the nearshore beach environment and open lake conditions. Results of this study are included in Chapter 2 of this WQIP.

Applicable Water Quality Standards

The designated uses of Nine Eagles Lake are: primary contact recreational use (Class A1); lakes and wetlands (Class B(LW)); and human health (Class HH). The designated uses are defined in the Iowa Administrative Code (567 Iowa Administrative Code, Chapter 61, (IAC)). For a more detailed description of the designated uses see Appendix B

Near Shore Beach Volume (NSBV)

The NSBV is the volume of water contained within the swimming zone of the Lake. Figure 6-5 shows the swimming and beach shed areas of Nine Eagles Lake. Table 6-3 is a summary of the NSBV data.

Figure 6-5. Swimming and Beach Shed Areas, Nine Eagles Lake.

Table 6-3. Nine Eagles NSBV Data.

Near Shore Beach Volume	0.89 acre-feet
Beach Front Length	286.8 feet
Radius from Shore at midpoint of beach	61.7 feet
Depth at Radius	4.2 feet (Elevation 933.8)
Beach Shed Area	4.4 Acres

Data Sources and Monitoring Sites

Table 6-4 lists the water quality monitoring locations used to develop the WQIP for Nine Eagles Lake. Figure 6-6 shows the monitoring locations used. In addition to these sites, samples were collected adjacent to the beach along three transects as shown in Figure 6-7. For a more detailed description of the samples collected along the transects see Chapter 2.

Table 6-4. WQ Data Monitoring Sites at Nine Eagles Lake.

Site Name	Site ID	Longitude	Latitude
NINEAG1(1)	14000146	93° 46' 07"	40° 36' 04"
NINEAG2(1)	14000147	93° 46' 02"	40° 35' 58"
NINEAG3(1)	14000148	93° 46' 06"	40° 35' 51"
Nine Eagles Lake(1) (2)	22270002	93° 46' 20"	40° 35' 48"
Nine Eagles Beach(2)	21270001	93° 45' 59"	40° 36' 00"

(1) 2015 Iowa DNR Study sampling site.
(2) Ambient water quality sampling site.

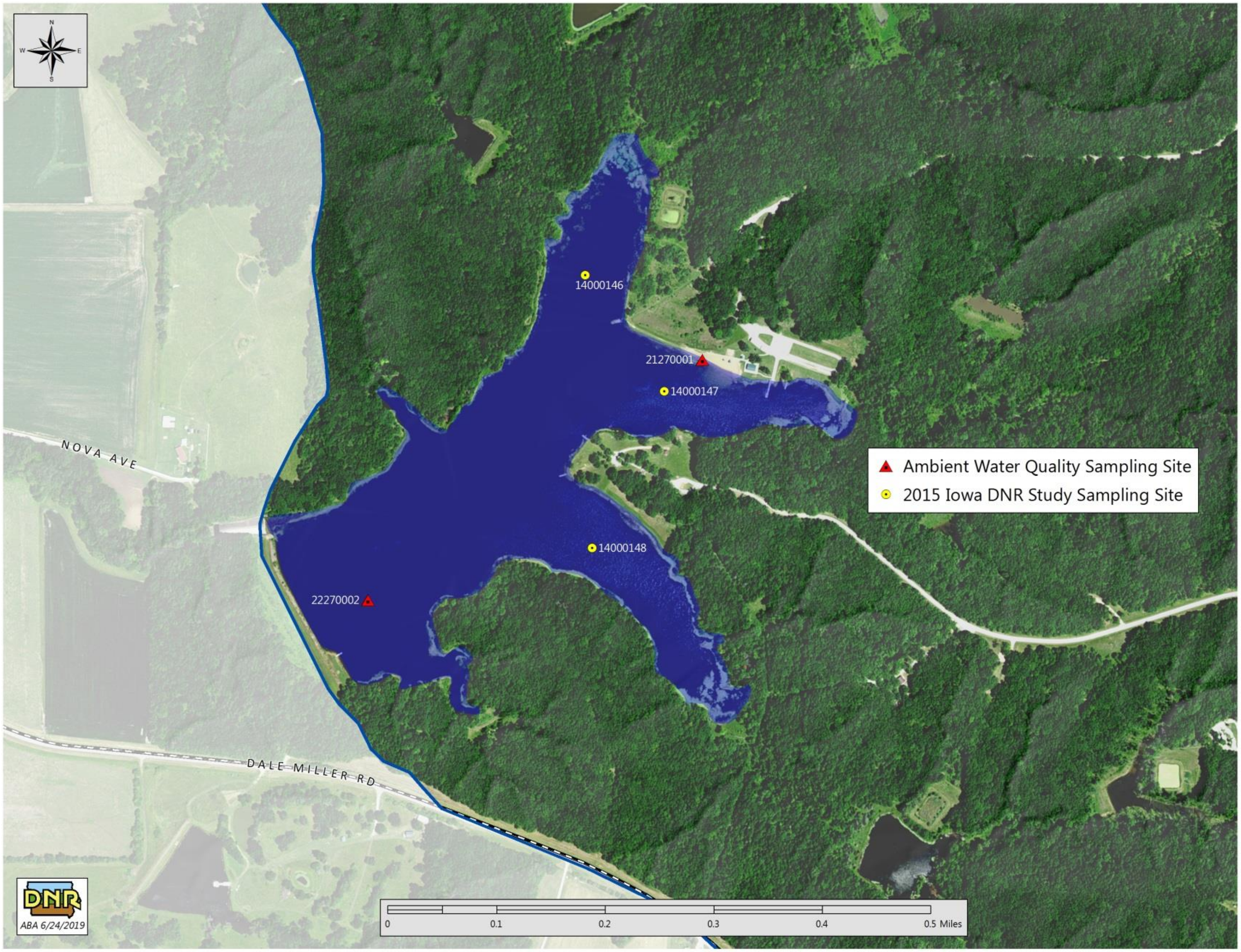


Figure 6-6. Sampling Locations, Nine Eagles Lake.

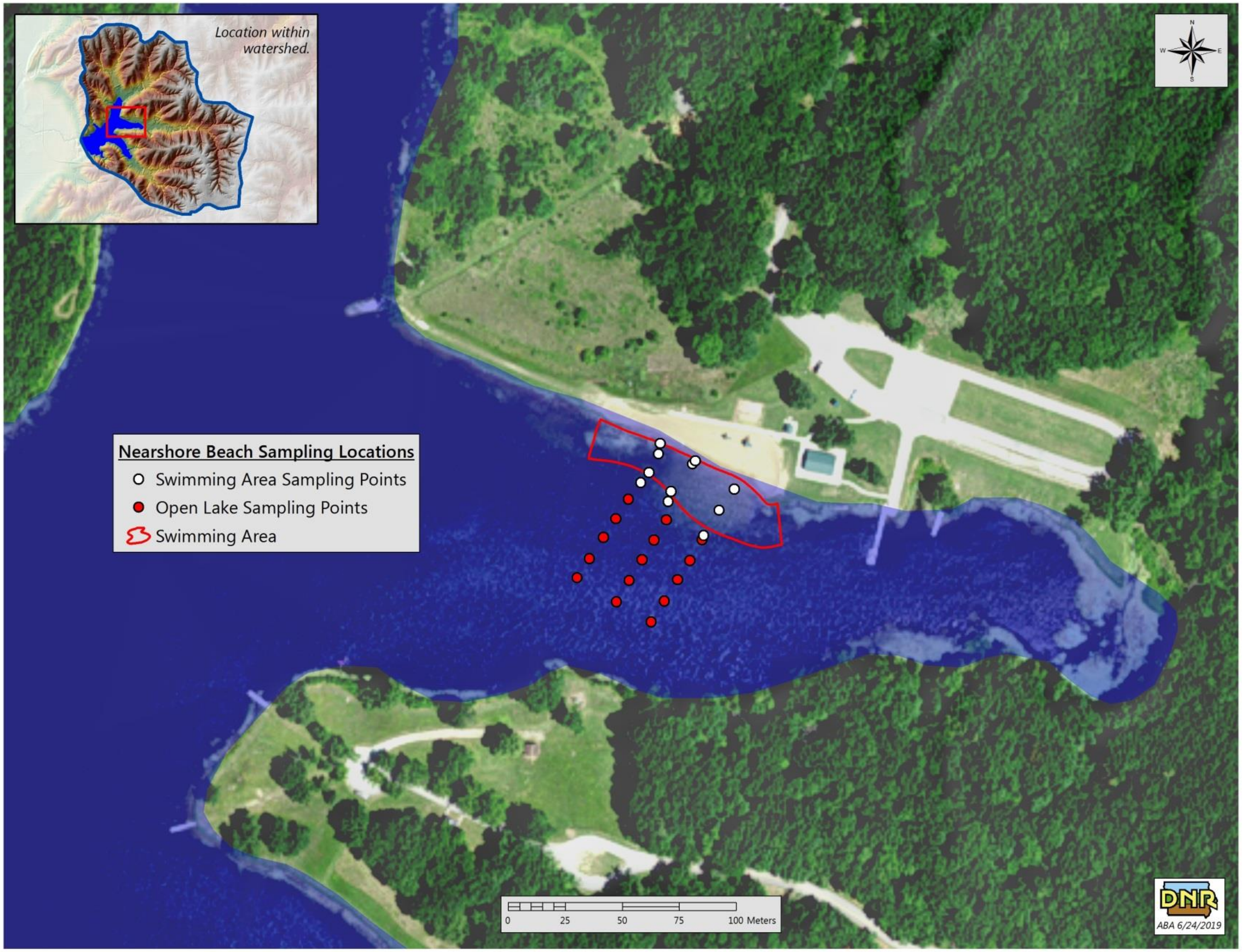


Figure 6-7. Nearshore Beach Sampling Locations, Nine Eagles Lake.

Interpretation of Data

Analysis of the data shows consistently high *E. coli* levels that exceed the criterion set for in Iowa's WQS for primary contact recreation. Significant reductions in *E. coli* loading will be required to comply with the standards and fully support the designated recreational use in the impaired waterbody.

Using data collected from 2004 – 2018, two box plots were developed. Figure 6-8 is a box plot of samples categorized by season (spring, summer, and fall) and a plot of the full data. The box has lines at the lower quartile, median, and upper quartile values. Whiskers extend from the top and bottom to the existing loading and the minimum load. The existing load for each box is the 90th percentile of observed *E. coli* concentrations. There is also a line representing the SSM concentration of 235 orgs/ 100 mL.

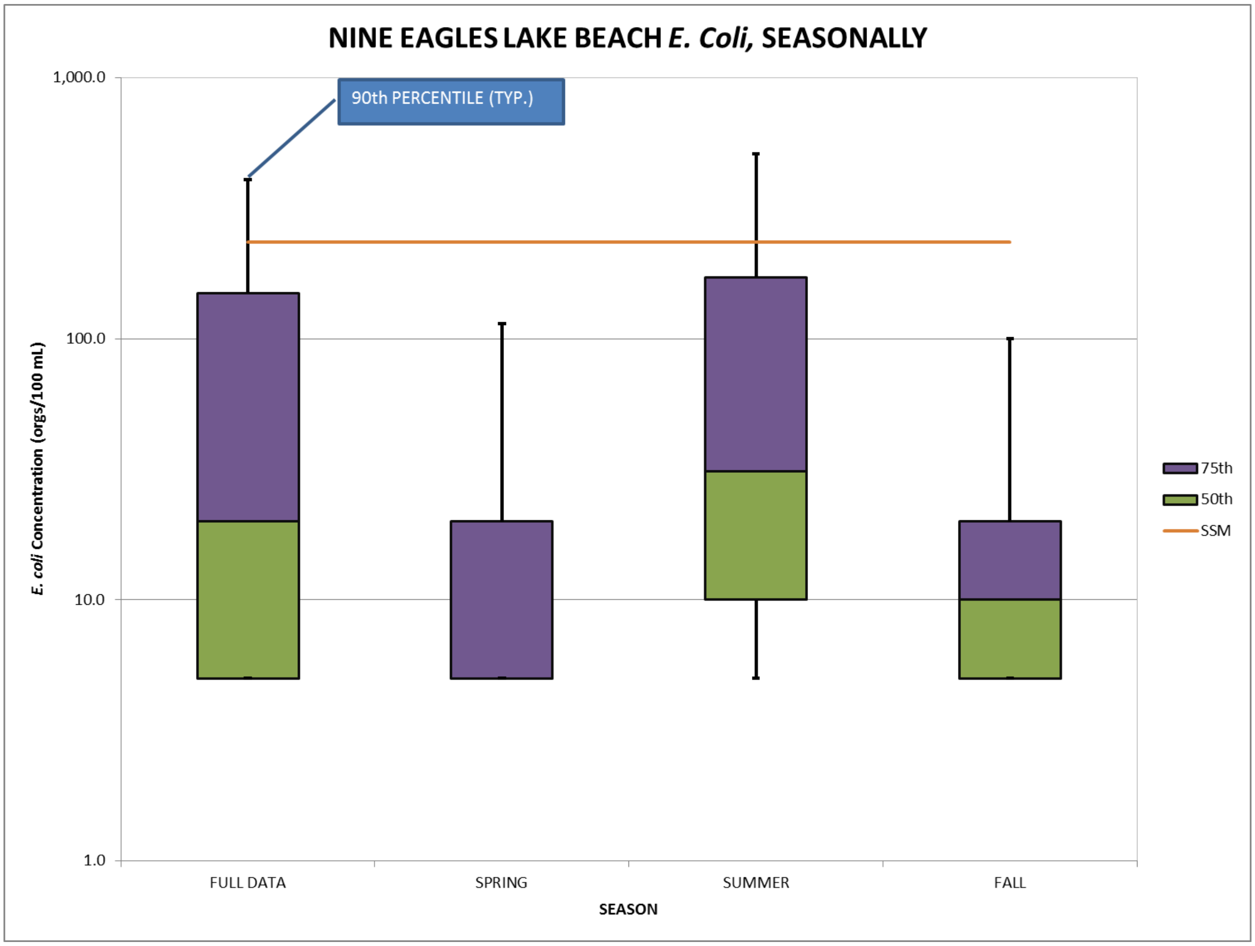


Figure 6-8. Seasonal Box Plot, Nine Eagles Lake.

From Figure 6-8 it can be seen that there are elevated levels of bacteria during the summer at the Nine Eagles Lake beach.

In the second box plot graph, Figure 6-9, data is categorized by month. This box plot has the same format as previously described. From this figure is can be seen that the level of bacteria is low in the early spring, increases in late spring and stays elevated until levels decrease in early fall, with a peak month of August.

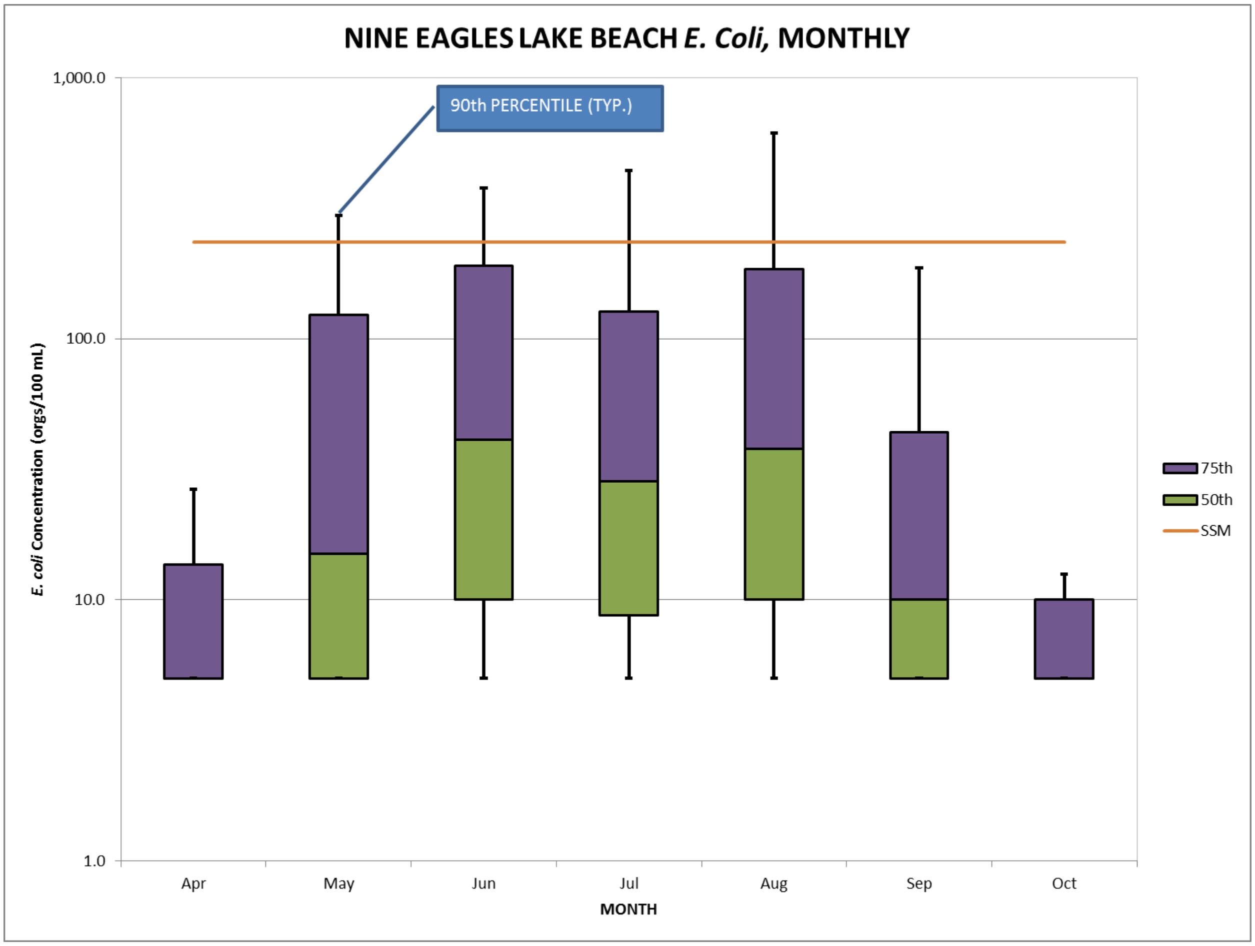


Figure 6-9. Monthly Box Plot, Nine Eagles Lake.

6.2.1. TMDL Target

General Description of Pollutant

Fecal material from warm-blooded animals contains many microorganisms. Some of these microorganisms can cause illness or disease if ingested by humans. The term pathogen refers to a disease-causing microorganism, and can include bacteria, viruses, and other microscopic organisms. Humans can become ill if they come into contact with and/or ingest water that contains pathogens.

Selection of Environmental Conditions

The critical period for the impairment occurs in the recreational season of March 15 to November 15. The critical volume is the NSBV, which is adjacent to the beach area.

Waterbody Pollutant Loading Capacity

Attainment of the WQS to fully support primary contact recreation requires that the GM for *E. coli* concentrations be no greater than 126 orgs/ 100 mL and the SSM be not greater than 235 orgs/ 100 mL (Iowa Administrative Code 567, Chapter 61, Water Quality Standards for Class A1 uses). The methods used to develop the *E. coli* TMDL for the Nine Eagles Lake are based on the assumption that compliance with the SSM will coincide with attainment of the GM target. Therefore, the loading capacity of the TMDL is the maximum number of *E. coli* organisms that can be in the NSBV while meeting the SSM criterion of 235 orgs/ 100 mL.

Decision Criteria for WQS Attainment
The seasonal duration curve was constructed using daily sampling data. The SSM criterion was used to quantify the loading capacity of the NSBV, in terms of load (orgs/ 100 mL). Points above the red SSM line in Figure 6-10 represent violations of the WQS, whereas points below the line comply with WQS.

WQS will be attained in the NSBV when less than 10% of samples exceed the SSM criterion of 235 orgs/ 100 mL during the recreational season of March 15 – November 15.

6.2.2. Pollution Source Assessment

Departure from Load Capacity
The seasonal load curve and observed loads for the seasonal load conditions are plotted in Figure 6-10. This methodology enables calculation of a TMDL target for each season. However, the highest percent reduction of the three seasons will be used as the target reduction for all impaired seasons. It is assumed if the highest percent reduction rate is used and achieved that WQS will be attained for GM and SSM criterion for all seasons.

Allowance for Increases in Pollutant Loads
A very high percentage of the land use within the Nine Eagles Lake watershed is forested or native vegetation. This land is steep to rolling hills, which would not lend itself to agriculture land use. In addition, the watershed is contained within the conservation and recreation lands owned and operated by the Iowa DNR. Consequently, it is unlikely that any new sources will be developed within the beach shed area of Nine Eagles Lake.

6.2.3. Pollutant Allocations

Wasteload Allocations (WLA)
There are no point sources in the watershed of Nine Eagles Lake. Therefore, the WLA portion of this TMDL is zero.

Load Allocation (LA)
Nonpoint sources result from livestock, pets, wildlife, and humans that live, work, and play in and around the stream. Specific examples of potential nonpoint sources of bacteria include animals directly depositing into streams, manure applied to row crops, manure runoff from grazed land, non-permitted onsite wastewater systems, and natural sources such as wildlife.

Based on the results of the 2-year study presented in Chapter 2 of this WQIP the source of the impairment is from the near shore beach environment. Source of *E. coli* is from water fowl loafing on the beach and regeneration of *E. coli* in the sand environment.

Margin of Safety
An explicit margin of safety (MOS) of 10 percent is applied to the calculation of loading capacities in this TMDL. Additionally, targeting the GM in each flow condition, rather than only the overall GM, provides an implicit MOS by requiring WQS compliance across flow conditions.

Seasonal Load Curve
Figure 6-10 shows a seasonal load curve for the NSBV at Nine Eagles Lake. Table 6-5 and Table 6-6 are the existing load estimates and the TMDL summary, respectively for the NSBV at Nine Eagles Lake.

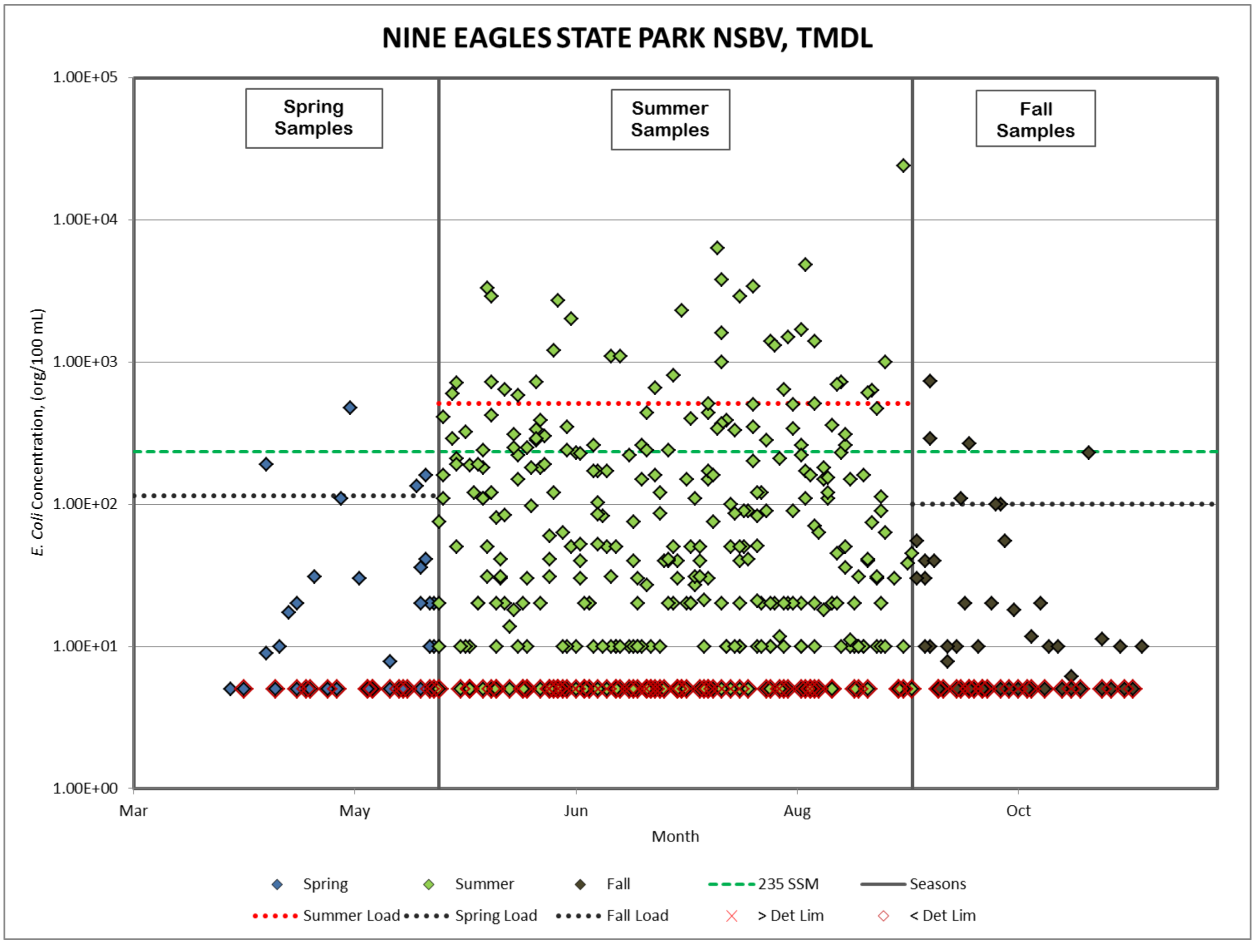


Figure 6-10. Seasonal Load Curve, Nine Eagles Lake, Near Shore Beach Volume.

Table 6-5. Existing Load Estimates for the NSBV at Nine Eagles Lake.

Load Summary	Seasonal Loads (org/ 100 mL)		
	Spring(1)	Summer	Fall(1)
Observed Load(2)	114.7	510.0	100.0
Departure	N/A	275	N/A
(% Reduction)	(0)	(53.9)	(0)

(1) Not assessed as impaired. Less than 10% of samples exceeded the SSM criterion of 235 orgs/ 100 mL.
(2) Observed load is the 90th percentile of water quality samples.

Table 6-6 is a summary of the TMDL for the NSBV at Nine Eagles Lake. Because it is assumed that the NSVB is constant from year to year the TMDL calculations do not change from season to season.

Table 6-6. TMDL Summary for the NSBV at Nine Eagles Lake.

	TMDL
TMDL (org/ 100 mL)	235.0
WLA (org/ 100 mL)	0.0
LA (org/ 100 mL)	211.5
MOS (org/ 100 mL))	23.5

6.2.4. TMDL Summary

This TMDL is based on meeting the water quality criteria for primary contact and children's recreation in Hickory Grove Lake. Although the WQS are based on *E. coli* concentration, the TMDL is also expressed as a load, in light of the November 2006 EPA memorandum. The following equation represents the total maximum daily load (TMDL) and its components:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

Where: TMDL = total maximum daily load
LC = loading capacity
ΣWLA = sum of wasteload allocations (point sources)
ΣLA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

Once the loading capacity, waste load allocations, load allocations, and margin of safety are determined for the lake, the general equation above can be expressed for *E. coli* as the allowable daily load. Using the values in Table 6-6 and a NSBV of 0.89 acre-feet the TMDL for Nine Eagles Lake as a mass loading is presented in Table 6-7.

Table 6-7. Summary of Nine Eagles Lake.

	TMDL
TMDL (orgs/day)	2.59E+06
WLA (orgs/day)	0.00E+00
LA (orgs/day)	2.33E+06
MOS (orgs/day)	2.59E+05

Appendix 6.A – Water Quality Data

Table 6.A-1. Water Quality Sampling Data, Beach Monitoring, Hickory Grove Lake, SITE ID 21270001.

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/2/1999	180	6/19/2000	< 10(2)	5/21/2002	< 10(2)
6/7/1999	20	6/26/2000	20	5/28/2002	< 10(2)
6/14/1999	280	7/5/2000	10	6/4/2002	< 10(2)
6/15/1999	180	7/10/2000	< 10(2)	6/11/2002	< 10(2)
6/21/1999	< 10(2)	7/17/2000	< 10(2)	6/18/2002	< 10(2)
6/22/1999	2,000	7/24/2000	< 10(2)	6/25/2002	< 10(2)
6/28/1999	170	7/31/2000	50	7/2/2002	< 10(2)
6/29/1999	82	8/7/2000	20	7/9/2002	< 10(2)
7/6/1999	40	8/14/2000	170	7/16/2002	30
7/7/1999	< 10(2)	8/21/2000	45	7/23/2002	170
7/12/1999	< 10(2)	8/28/2000	40	7/30/2002	2,900
7/13/1999	< 10(2)	9/5/2000	10	8/5/2002	< 10(2)
7/19/1999	50	9/11/2000	10	8/13/2002	10
7/20/1999	27	9/18/2000	< 10(2)	8/20/2002	360
7/26/1999	20	5/23/2001	< 10(2)	8/26/2002	< 10(2)
7/27/1999	390	5/29/2001	10	9/3/2002	30
8/2/1999	350	6/4/2001	120	9/10/2002	30
8/3/1999	82	6/11/2001	20	9/17/2002	10
8/9/1999	10	6/18/2001	120	9/24/2002	< 10(2)
8/10/1999	< 10(2)	6/19/2001	2700	10/1/2002	< 10(2)
8/16/1999	20	6/25/2001	< 10(2)	10/8/2002	10
8/17/1999	< 10(2)	7/2/2001	10	10/15/2002	< 10(2)
8/23/1999	36	7/9/2001	27	10/22/2002	< 10(2)
8/24/1999	150	7/16/2001	< 10(2)	10/29/2002	10
8/30/1999	10	7/23/2001	150	4/14/2003	190
8/31/1999	10	7/30/2001	20	4/21/2003	< 10(2)
9/7/1999	< 10(2)	8/6/2001	1,400	4/28/2003	< 10(2)
9/8/1999	55	8/13/2001	20	5/5/2003	30
9/13/1999	< 10(2)	8/20/2001	< 10(2)	5/12/2003	< 10(2)
9/14/1999	< 10(2)	8/27/2001	10	5/19/2003	36
9/20/1999	< 10(2)	9/4/2001	< 10(2)	5/27/2003	50
9/21/1999	< 10(2)	9/10/2001	10	6/2/2003	< 10(2)
9/27/1999	100	9/10/2001	40	6/9/2003	18
9/28/1999	55	4/16/2002	< 10(2)	6/16/2003	300
5/22/2000	20	4/23/2002	< 10(2)	6/23/2003	230
5/30/2000	10	4/30/2002	< 10(2)	6/30/2003	50
6/5/2000	80	5/7/2002	< 10(2)	7/7/2003	20
6/12/2000	30	5/14/2002	< 10(2)	7/14/2003	240
7/21/2003	40	8/1/2005	90	6/12/2007	< 10(2)
7/28/2003	50	8/8/2005	210	6/19/2007	< 10(2)

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
8/4/2003	120	8/15/2005	160	6/25/2007	< 10(2)
8/11/2003	340	8/22/2005	720	7/2/2007	10
8/18/2003	18	8/29/2005	630	7/10/2007	10
8/25/2003	10	9/5/2005	< 10(2)	7/16/2007	< 10(2)
9/1/2003	10	9/12/2005	40	7/23/2007	< 10(2)
9/8/2003	30	9/19/2005	20	7/30/2007	10
9/15/2003	10	9/26/2005	100	8/6/2007	10
9/22/2003	10	10/3/2005	< 10(2)	8/13/2007	10
9/29/2003	< 10(2)	10/10/2005	10	8/20/2007	20
10/6/2003	20	10/17/2005	230	8/27/2007	160
10/13/2003	< 10(2)	10/24/2005	10	5/19/2008	< 10(2)
10/20/2003	< 10(2)	4/17/2006	10	5/27/2008	210
10/27/2003	< 10(2)	4/24/2006	< 10(2)	6/3/2008	3,300
7/19/2004	20	5/1/2006	110	6/4/2008	720
7/26/2004	1,000	5/8/2006	< 10(2)	6/10/2008	220
8/2/2004	3,400	5/15/2006	< 10(2)	6/17/2008	< 10(2)
8/9/2004	640	5/22/2006	< 10(2)	6/24/2008	40
8/16/2004	70	5/30/2006	< 10(2)	6/26/2008	20
8/23/2004	50	6/5/2006	< 10(2)	7/1/2008	10
8/30/2004	30	6/12/2006	< 10(2)	7/2/2008	50
9/7/2004	45	6/19/2006	< 10(2)	7/8/2008	150
9/13/2004	< 10(2)	6/26/2006	< 10(2)	7/9/2008	440
9/20/2004	< 10(2)	7/3/2006	< 10(2)	7/15/2008	50
9/27/2004	< 10(2)	7/10/2006	< 10(2)	7/16/2008	40
10/4/2004	< 10(2)	7/17/2006	2300	7/21/2008	50
10/11/2004	< 10(2)	7/24/2006	160	7/23/2008	30
10/25/2004	< 10(2)	7/31/2006	90	7/29/2008	330
5/16/2005	< 10(2)	8/7/2006	1,300	7/30/2008	40
5/23/2005	20	8/14/2006	4,800	8/4/2008	20
5/30/2005	< 10(2)	8/21/2006	690	8/6/2008	20
6/6/2005	30	8/28/2006	610	8/11/2008	90
6/13/2005	180	9/5/2006	24,000	8/13/2008	260
6/20/2005	< 10(2)	9/11/2006	290	8/18/2008	150
6/27/2005	10	9/18/2006	110	8/26/2008	10
7/5/2005	< 10(2)	9/25/2006	20	5/20/2009	160
7/11/2005	< 10(2)	5/22/2007	10	5/27/2009	190
7/18/2005	20	5/30/2007	187	6/2/2009	240
7/25/2005	6,300	6/5/2007	20	6/3/2009	50
6/9/2009	310	5/24/2011	110	7/2/2013	< 10(2)
6/10/2009	150	6/1/2011	20	7/9/2013	< 10(2)
6/16/2009	190	6/8/2011	< 10(2)	7/16/2013	< 10(2)
6/17/2009	60	6/15/2011	< 10(2)	7/18/2013	< 10(2)

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
6/23/2009	10	6/21/2011	10	7/23/2013	440
6/24/2009	30	6/28/2011	< 10(2)	7/24/2013	75
6/30/2009	< 10(2)	7/6/2011	< 10(2)	7/30/2013	10
7/7/2009	10	7/12/2011	10	7/30/2013	< 10(2)
7/8/2009	10	7/20/2011	31	8/6/2013	10
7/14/2009	40	7/27/2011	10	8/13/2013	< 10(2)
7/15/2009	20	8/3/2011	51	8/14/2013	< 10(2)
7/21/2009	< 10(2)	8/10/2011	1500	8/20/2013	< 10(2)
7/22/2009	10	8/16/2011	510	8/27/2013	10
7/27/2009	10	8/22/2011	230	8/28/2013	< 10(2)
7/30/2009	50	8/31/2011	20	9/4/2013	< 10(2)
8/3/2009	10	5/23/2012	10	9/17/2013	< 10(2)
8/5/2009	90	5/30/2012	< 10(2)	9/23/2013	< 10(2)
8/11/2009	500	6/5/2012	< 10(2)	4/9/2014	< 10(2)
8/13/2009	1,700	6/12/2012	10	4/21/2014	20
8/18/2009	180	6/20/2012	10	5/7/2014	< 10(2)
8/19/2009	110	6/27/2012	170	5/20/2014	41
8/25/2009	< 10(2)	7/3/2012	10	5/21/2014	10
9/1/2009	1000	7/9/2012	< 10(2)	5/28/2014	10
5/26/2010	600	7/17/2012	< 10(2)	6/3/2014	31
6/2/2010	110	7/23/2012	< 10(2)	6/4/2014	2,900
6/7/2010	640	8/1/2012	41	6/10/2014	580
6/9/2010	250	8/6/2012	< 10(2)	6/12/2014	250
6/15/2010	390	8/15/2012	< 10(2)	6/17/2014	41
6/22/2010	50	8/21/2012	20	6/17/2014	31
6/29/2010	10	8/28/2012	41	6/24/2014	52
7/7/2010	30	4/25/2013	31	7/1/2014	1,100
7/13/2010	40	5/8/2013	< 10(2)	7/1/2014	31
7/20/2010	110	5/21/2013	20	7/8/2014	260
7/26/2010	370	5/29/2013	320	7/9/2014	240
7/28/2010	100	6/4/2013	420	7/14/2014	20
8/3/2010	120	6/5/2013	10	7/15/2014	810
8/10/2010	20	6/11/2013	< 10(2)	7/22/2014	< 10(2)
8/16/2010	< 10(2)	6/17/2013	< 10(2)	7/23/2014	510
8/24/2010	10	6/18/2013	1,200	7/28/2014	< 10(2)
8/31/2010	90	6/25/2013	20	7/29/2014	10
8/5/2014	280	9/15/2015(3)	8	6/14/2017	290
8/13/2014	220	9/30/2015(3)	18	6/21/2017	350
8/14/2014	110	10/13/2015(3)	6	6/28/2017	85
8/19/2014	120	10/20/2015(3)	11	7/5/2017	220
8/26/2014	31	4/6/2016(3)	5	7/12/2017	120
8/26/2014	10	4/19/2016(3)	17	7/19/2017	20

Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)	Date	*E. coli* (orgs/ 100 mL)
9/11/2014	730	5/3/2016(3)	479	7/26/2017	1,600
9/23/2014	< 10(2)	5/18/2016(3)	133	8/2/2017	500
10/7/2014	< 10(2)	5/24/2016	160	8/9/2017	20
4/14/2015(3)	8.9	6/1/2016(3)	190	8/16/2017	1,400
4/28/2015(3)	5	6/1/2016	20	8/23/2017	310
5/12/2015(3)	8	6/6/2016	31	8/30/2017	470
5/19/2015	20	6/14/2016(3)	336	5/23/2018	75
5/26/2015(3)	288	6/14/2016	720	5/30/2018	< 10(2)
5/27/2015	710	6/21/2016	240	6/6/2018	41
6/2/2015	110	6/28/2016(3)	102	6/13/2018	97
6/8/2015(3)	14	6/28/2016	52	6/20/2018	63
6/10/2015	10	7/6/2016	75	6/27/2018	260
6/15/2015	20	7/11/2016	159	7/3/2018	1,100
6/23/2015	< 10(2)	7/12/2016	86	7/11/2018	660
6/24/2015(3)	226	7/19/2016	400	7/18/2018	150
6/30/2015	170	7/26/2016(3)	3,800	7/25/2018	340
7/6/2015(3)	10	7/26/2016	< 10(2)	8/1/2018	< 10(2)
7/7/2015	10	8/2/2016	200	8/8/2018	< 10(2)
7/14/2015	41	8/8/2016(3)	12	8/15/2018	< 10(2)
7/21/2015	31	8/9/2016	< 10(2)	8/22/2018	10
7/22/2015(3)	21	8/16/2016	10	8/29/2018	74
7/29/2015	86	8/23/2016	260		
8/3/2015(3)	21	8/24/2016(3)	11		
8/4/2015	10	8/30/2016	31		
8/11/2015	20	9/6/2016(3)	38	Min =	5
8/17/2015	63	9/20/2016(3)	265	1st Quartile =	5
8/19/2015(3)	153	10/4/2016(3)	12	Median =	20
8/25/2015	20	5/24/2017	410	3rd Quartile =	150
8/31/2015(3)	112	5/31/2017	120	Max =	24,000
9/1/2015	63	6/7/2017	84	Mean =	246

(1) Unless noted samples collected by the Iowa DNR as part of Ambient water quality monitoring.
(2) E. coli was not detectable. The minimum detection limit is 10 org/100 mL. Consequently, 5 org/100 mL was used in calculations.
(3) Samples collected by Iowa DNR as part of 2015 study.

Appendix A. References

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Appendix B. Glossary of Terms, Abbreviations, and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and / or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.

AU: Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.2 AU.

Benthic: Associated with or located at the bottom (in this context, "bottom" refers to the bottom of streams, lakes, or wetlands). Usually refers to algae or other aquatic organisms that reside at the bottom of a wetland, lake, or stream (see periphyton).

Benthic macroinvertebrates: Animals larger than 0.5 mm that do not have backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Base flow: Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.

Biological impairment: A stream segment is classified as biologically impaired if one or more of the following occurs, the FIBI and or BMIBI scores fall below biological reference conditions, a fish kill has occurred on the segment, or the segment has seen a > 50% reduction in mussel species.

Biological reference condition: Biological reference sites represent the least disturbed (i.e. most natural) streams in the ecoregion. The biological data from these sites are used to derive least impacted BMIBI and FIBI scores for each ecoregion. These scores are used to develop Biological Impairment Criteria (BIC) scores for each ecoregion. The BIC is used to determine the impairment status for other stream segments within an ecoregion.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Concentrated Animal Feeding Operation. A federal term defined as any animal feeding operation (AFO) with more than 1000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into any ditch, stream, or other water conveyance system, whether man-made or natural.

CBOD5:	5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.
CFU:	A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.
Confinement feeding operation:	An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.
Credible data law:	Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered “credible,” data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).
Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or Iowa DNR):	Iowa Department of Natural Resources.
Ecoregion:	Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.
EPA (or USEPA):	United States Environmental Protection Agency.
Ephemeral gully erosion:	Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
Geometric Mean (GM):	A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa’s water quality standards and assessment procedures, the geometric mean criterion for *E. coli* is measured using at least five samples collected over a 30-day period.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Groundwater:	Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.
Gully erosion:	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

IDALS: Iowa Department of Agriculture and Land Stewardship

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)

LiDAR: Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.

Load: The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.

Macrophyte: An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.

MOS: Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.

MPN: Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.

MS4: Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.

Nonpoint source pollution: Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.

NPDES: National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.

Open feedlot:	An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.
Periphyton:	Algae that are attached to substrates (rocks, sediment, wood, and other living organisms). Are often located at the bottom of a wetland, lake, or stream.
Phytoplankton:	Collective term for all photosynthetic organisms suspended in the water column. Includes many types of algae and cyanobacteria.
Point source pollution:	Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by a federal NPDES permit.
Pollutant:	As defined in Clean Water Act section 502(6), a pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.
Pollution:	The man-made or man-induced alteration of the chemical, physical, biological, and/or radiological integrity of water.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/L).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/L).
RASCAL:	Rapid Assessment of Stream Conditions Along Length. RASCAL is a global positioning system (GPS) based assessment procedure designed to provide continuous stream and riparian condition data at a watershed scale.
Riparian:	Refers to areas near the banks of natural courses of water. Features of riparian areas include specific physical, chemical, and biological characteristics that differ from upland (dry) sites. Usually refers to the area near a bank of a stream or river.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Scientific notation:	See explanation on page 107.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (typically measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion that is delivered to the waterbody of concern.
Seston:	All particulate matter (organic and inorganic) suspended in the water column.
Sheet & rill erosion:	Sheet and rill erosion is the detachment and removal of soil from the land surface by raindrop impact, and / or overland runoff. It occurs on slopes with overland flow and where runoff is not concentrated.
Single-Sample Maximum (SSM):	A water quality standard criterion used to quantify *E. coli* levels. The single-sample maximum is the maximum allowable concentration measured at a specific point in time in a waterbody.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The discharge (flow) from surface runoff generated by a precipitation event. *Stormwater* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that treats municipal sewage prior to discharge to a waterbody according to the conditions of an NPDES permit.

SWCD:	Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
TDS:	Total Dissolved Solids: The quantitative measure of matter (organic and inorganic material) dissolved, rather than suspended, in the water column. TDS is analyzed in a laboratory and quantifies the material passing through a filter and dried at 180 degrees Celsius.
TMDL:	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses. A TMDL is mathematically defined as the sum of all individual wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).
Trophic state:	The level of ecosystem productivity, typically measured in terms of algal biomass.
TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system developed by Carlson (1977) that places trophic state on an exponential scale of Secchi depth, chlorophyll, and total phosphorus. TSI ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.
TSS:	Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended, rather than dissolved, in the water column. TSS is analyzed in a laboratory and quantifies the material retained by a filter and dried at 103 to 105 degrees Celsius.
Turbidity:	A term used to indicate water transparency (or lack thereof). Turbidity is the degree to which light is scattered or absorbed by a fluid. In practical terms, highly turbid waters have a high degree of cloudiness or murkiness caused by suspended particles.
UAA:	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)
UHL:	University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring, ambient monitoring, biological reference monitoring and impaired water assessments.
USDA:	United States Department of Agriculture
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.
Watershed:	The land area that drains water (usually surface water) to a particular waterbody or outlet.
WLA:	Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).
WQS:	Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.
WWTF:	Wastewater Treatment Facility. General term for a facility which treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit. Used interchangeably with wastewater treatment plant (WWTP).
Zooplankton:	Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation
Scientific notation is the way that scientists easily handle very large numbers or very small numbers. For example, instead of writing 45,000,000,000 we write 4.5E+10. So, how does this work?

We can think of 4.5E+10 as the product of two numbers: 4.5 (the digit term) and E+10 (the exponential term).
Here are some examples of scientific notation.

10,000 = 1E+4	24,327 = 2.4327E+4
1,000 = 1E+3	7,354 = 7.354E+3
100 = 1E+2	482 = 4.82E+2
1/ 100 = 0.01 = 1E-2	0.053 = 5.3E-2
1/1,000 = 0.001 = 1E-3	0.0078 = 7.8E-3
1/10,000 = 0.0001 = 1E-4	0.00044 = 4.4E-4

As you can see, the exponent is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left.

Appendix C. General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's WQS apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published WQS, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published WQS, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table C-1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published WQS, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table C-1. Designated Use Classes for Iowa Water Bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix D. DNR Project Files and Locations

This appendix is primarily for future reference by DNR staff that may wish to access the original spreadsheets, models, maps, figures, and other files utilized in the development of the TMDL.

Table D-1. Project Files and Locations.

Directory\folder path	File name	Description
\\iowa.gov.state.ia.us\data\DNR_WQB_WIS_TMDL\Draft_TMDLs\BeachOnly_Bacteria\Modeling\	TMDL_Ecoli_Data.xlsx	General Summary of all lakes. Includes tabs with WQ Data, TMDL calculations, and seasonal and monthly WQ data.
\\iowa.gov.state.ia.us\data\DNR_WQB_WIS_TMDL\Draft_TMDLs\BeachOnly_Bacteria\Data\Analysis	Various files, File Type: .XLSX Example: “Rainfall HGL.xlsx”. This is precipitation and evapotranspiration data for Hickory Grove Lake.	Precipitation and Evapotranspiration Data.
\\iowa.gov.state.ia.us\data\DNR_GIS_Data\NASS\National_cropland_data_layer\CDL_2014\03RECODE\Grids. (Location of original file)	cdl2014rc, Raster File	National Crop Land Layer. This was used to generate Land Use Coverage data and statistics.
\\iowa.gov.state.ia.us\data\DNR_WQB_WIS_TMDL\Draft_TMDLs\Iowa_River_Basin\Documents, Presentations\References	Various .pdf and .docx files	References cited in the WQIP and/or utilized to develop model input parameters
\\iowa.gov.state.ia.us\data\DNR_WQB_WIS_TMDL\Draft_TMDLs\BeachOnly_Bacteria\GIS\GIS_Data	Various shapefiles (.shp) and raster files (.grd)	Used to develop models and maps

Appendix E. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in the Iowa Lakes.

As additional beach bacteria TMDLs are prepared and public meetings held, Appendix E will be amended to reflect the new submittals.

E.1. Public Meetings

Public information meetings are scheduled for each beach bacteria TMDL at the following locations, dates, and times:

- Nine Eagles Lake
  Lamoni Community Center
  108 S Chestnut St
  Lamoni, Iowa
  March 18, 2020, 6 – 7:30 pm

- Hickory Grove Lake
  Nevada Senior Community Center
  1231 6th Street
  Nevada, Iowa
  March 24, 2020, 6 – 7:30 pm

- Clear Lake
  Lake View Room
  10 North Lake View Dr.
  Clear Lake, Iowa
  April 1, 2020, 6 – 7:30 pm

Table E-1 is a listing of public meetings that have been held. As additional beach bacteria TMDLs are prepared and public meetings are held, Table E-1 will be amended to reflect those updates.

Table E-1. Past Public Meetings.

Lake	Location	Date & Time	WQIP Chapter	Amendment No.

E.2. Written Comments

A press release will be issued on March 5, 2020 to begin a 45-day public comment period which will end on April 20, 2020.

E.3. Public Comments

Public Comment:
All public comments received during the public comment period will be placed in this section, along with Iowa DNR responses.